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DEADLOAD CALIBRATION PROGRAM OF CVN 68 CATAPULT CONFIGURATION.(U)

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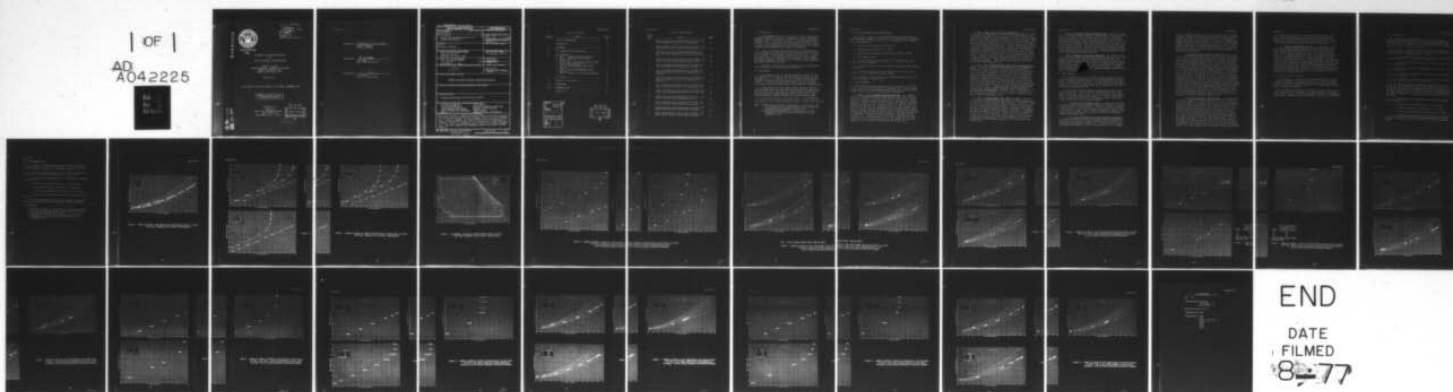
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DEADLOAD CALIBRATION PROGRAM  
OF  
CVN 68 CATAPULT CONFIGURATION

Edward J. Yesunas  
Launching Division, Engineering Department  
Naval Air Test Facility  
Lakehurst, New Jersey 08733

9 March 1977

Final Report for Period 28 August 1972 Through 17 November 1976

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Prepared for  
Commander  
Naval Air Systems Command  
JP-2 (AIR-537)  
Washington, D.C. 20361

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 14 NATF-EN-1137	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEADLOAD CALIBRATION PROGRAM OF CVN 68 CATAPULT CONFIGURATION.		5. TYPE OF REPORT & PERIOD COVERED FINAL rept. 28 Aug 1972 - 17 Nov 1976
7. AUTHOR(s) 10 EDWARD J. YESUNAS		6. PERFORMING ORG. REPORT NUMBER NATF-EN-1137
9. PERFORMING ORGANIZATION NAME AND ADDRESS NAVAL AIR TEST FACILITY (4120) NAVAL AIR STATION LAKEHURST, NEW JERSEY 08733		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS NAVAL AIR SYSTEMS COMMAND JP-2 (AIR-537) WASHINGTON, D.C. 20361		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 98, 0050, 001, 53721-00
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 37p.		12. REPORT DATE 11 9 March 1977
		13. NUMBER OF PAGES 23
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES  PREPARED UNDER AIRTASK A5375372 0714 6537000017		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) WET-STEAM ACCUMULATOR      STEAM CATAPULT CAPACITY SELECTOR VALVE      WET-STEAM ACCUMULATOR WATER LEVEL STEAM-PRESSURE CUTOFF SWITCH      HYDRAULIC SYSTEM PRESSURE WATER SUBSATURATION TEMPERATURE      STEAM PRESSURE CVN 68      STANDARD CATAPULT CONFIGURATION		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes a deadload calibration program conducted at the Naval Air Test Facility with the TC13 Mod 1 catapult in the final CVN 68 configuration. During the program, the standard CVN 68 catapult configuration was tested and then various catapult control parameters were varied during tests in order to clarify the operational limits of the CVN 68 catapult configuration. Tests were conducted with deadloads weighing from 10,500 to 84,500 pounds.		

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## I INTRODUCTION

A. The NAVAIRENGCEN (*Naval Air Engineering Center*) conducted a development program on the low-loss launching-valve (duplex plug type), metering rod, and CSV (*capacity selector valve*) spindle for the CVN 68 catapults. After that program was completed, the NAVAIRTESTFAC (*Naval Air Test Facility*) conducted a long-term deadload calibration program to evaluate the finalized CVN 68 catapult configuration. The TC13 Mod 1 catapult at the NAVAIRTESTFAC was used for both programs.

B. During the deadload calibration program, the finalized CVN 68 launching system was tested over the full operating range of the catapult to evaluate various catapult parameters and their effect on catapult performance. The parameters to be evaluated were: steam accumulator pressure, steam cutoff switch location, steam accumulator water/steam temperature differential ( $\Delta T$ ), hydraulic system pressure, and steam accumulator water level.

C. Reference (a) reports on the evaluation of the CVN 68 catapult control systems and associated catapult components.

## II BACKGROUND

A. From previous tests, it has been determined that the CSV spindle, NAEC PN 510721-1, used for the roto launching valves on the USS MIDWAY (CV 41) (reference (b)), will not produce satisfactory performance when used with the roto launching valves on the USS NIMITZ (CVN 68). A CV 67-type spindle used during the initial development tests proved satisfactory and was used in the final CVN 68 configuration.

B. NAVSEASYSKOM (*Naval Sea Systems Command*) requested that the operating steam pressure of the catapults on the CVN 68 be reduced from 600 psig to 520 psig. The request for reduced operating pressure was made to increase the longevity of the ship's nuclear reactor. The 600-psig capability would be retained only as an emergency standby.

C. A detailed description of the operation of a constant-pressure wet-steam accumulator system in conjunction with a capacity-selector-valve assembly and a roto-launching-valve assembly is given in reference (b).

- Ref: (a) NAVAIRTESTFAC Report No. NATF-EN-1117 of 22 Dec 1971: Initial Evaluation of Integrated Catapult Control Station and Associated Catapult Equipment for the CVN 68
- (b) NAVAIRTESTFAC Letter Report No. NATF-L75 of 21 Oct 1970: Evaluation of the final catapult configuration for the USS MIDWAY (CV 41)

### III TEST EQUIPMENT AND CONFIGURATION

The TC13 Mod 1 catapult at the NAVAIRTESTFAC was configured with the following basic components to simulate the final CVN 68 catapult configuration. (All numbers cited in this report are NAVAIRENGCEN part numbers unless stated otherwise.)

- A. Low-loss roto launching valves, 614558-6
- B. Launching-valve metering rod, 515270-2
- C. Launching-valve hydraulic-actuator orifice snubber, 419480-2
- D. CSV spindle, 514364-1
- E. C13 Mod 1 Catapult Service Change No. 117 (super seals) cover seals on the piston assemblies
- F. A 3/4-inch-diameter orifice was installed in the pressure-breaking orifice elbow
- G. A 1/16-inch-diameter orifice was installed in port "A" of the keeper valve on the exhaust-valve panel assembly
- H. A 1/2-inch-diameter orifice (line size) was installed in port "E" of the launching-valve control valve.

### IV TEST PROCEDURE

The deadload calibration program consisted of six parts. Part 1 was conducted to evaluate the standard operating conditions. Parts 2 through 6 were conducted to determine catapult performance and to establish operational limits for the final CVN 68 catapult configuration.

A. PART 1 - TEST OF STANDARD OPERATING CONDITIONS: The standard operating configuration/conditions evaluated were as follows: wet-steam accumulator pressure, 520  $\pm$  5 psig; water level in the wet-steam accumulator, 50  $\pm$  2 inches; hydraulic system pressure, 2,500  $\pm$  50 psig; cylinder elongation, between 7.0 and 7.8 inches; wet-steam accumulator water/steam temperature differential ( $\Delta T$ ), no greater than 5° F; and steam cutoff switch located 210 feet from catapult station zero. The tolerance limits of the above conditions were maintained by site operating personnel and, wherever possible, reduced so that the results produced for the standard operating conditions yielded the most exact data. This data was then used for comparison purposes with the data obtained in the tests of Parts 2 through 6 below. Deadloads weighing from 10,250 to 84,500 pounds were used during the evaluation period. CSV settings ranged from 10 to 320; however, during certain deadload launchings the maximum CSV setting was limited so as not to exceed a catapult end speed of 175 knots.

B. PART 2 - WATER LEVEL IN WET-STEAM ACCUMULATOR: Prior to a catapult launch, the steam and water in the wet-steam accumulator are near thermodynamic equilibrium. This condition exists when the water temperature is close enough to saturation temperature that the water will flash to steam if the vapor (steam) pressure above the water is reduced a small amount. During a catapult launch, steam energy is expended in moving the catapult piston assemblies when the launching valve is opened and results in an accumulator pressure drop. Because a thermodynamic unbalance is created, the water-mass temperature is greater than the saturation temperatures corresponding to the reducing pressures. This state of thermodynamic unbalance tends to move toward equilibrium by the vaporization of a portion of the water mass to steam (regeneration), and the amount of steam regeneration is partially determined by the water level in the accumulator. Tests were conducted using various wet-steam accumulator water levels (35 and 55 inches) to investigate their effect on catapult performance. Deadloads weighing 10,500, 35,700/36,100, 47,200, and 84,100 pounds were used.

C. PART 3 - WET-STEAM ACCUMULATOR WATER/STEAM TEMPERATURE DIFFERENTIAL: A specific accumulator charge pressure has a corresponding temperature for saturated steam. A controlling steam-regeneration factor is the number of degrees Fahrenheit the accumulator water is below the saturation temperature for the corresponding charge pressure (water subsaturation temperature differential). To accomplish the steam/water temperature differential ( $\Delta T$ ), the steam accumulator was charged to a pressure lower than the required 520 psig (results in a lower water temperature); then steam was injected, by use of special test-site piping, immediately above the waterline to bring the accumulator up to the required pressure (creating a temperature differential of the required range). It should be noted that this condition could occur only if a serious casualty happened to the wet accumulator internal steam charging system. This part of the program was conducted with temperature differentials ( $\Delta T$ ) of 10 and 15° F to determine at what  $\Delta T$  catapult performance is affected. Deadloads weighing 14,600, 35,700, and 84,100 pounds were used.

D. PART 4 - STEAM-PRESSURE CUTOFF-SWITCH LOCATIONS: The steam-actuated pressure switch initiates the closing of the launching valves at a specific position during the launching stroke. The pressure switch is actuated by the steam pressure behind the piston assemblies as they pass the cutoff-switch location. Ideally, to minimize steam expenditure, the closest pressure-switch location to catapult station zero that would not impair catapult performance is desirable. To determine the optimum location for the cutoff switch, the switch was positioned forward of the standard (210-foot) location to 222 feet forward of catapult station zero. The switch was then moved aft until a decrease in end speed was experienced. Tests were conducted at the various positions with deadloads weighing 10,250/10,500, 35,700/36,100, and 74,300 pounds.

E. PART 5 - WET-STEAM ACCUMULATOR STEAM PRESSURE: Should the nuclear reactor be unable to supply the steam accumulator with the required 520  $\pm$  5 psig, or the automatic steam charging system malfunction, it would be necessary to operate the catapult at other than normal steam pressures. Under normal operating conditions (automatic charging), the wet-steam accumulator steam pressure could be easily maintained at 520  $\pm$  5 psig. Tests were conducted to determine what tolerance limit on steam pressure would affect catapult end speed. Tests were conducted using various wet-steam accumulator pressures (475, 500, 550, and 575 psig) to determine their effect on deadload end speed and acceleration. Deadloads weighing 14,600, 36,100, and 84,100/84,400 pounds were used.

F. PART 6 - HYDRAULIC-SYSTEM SUPPLY PRESSURES: The catapult launching valve is opened and closed by constant-pressure hydraulic fluid. The opening rate of the launching valve is partially controlled by the hydraulic-system supply pressure; therefore, varying the hydraulic-system supply pressure alters the opening rate of the launching valve which directly affects catapult performance. Tests were conducted at hydraulic-system pressures of 2,200, 2,400, 2,600, and 2,700 psig to determine their effect on catapult performance. Deadloads weighing 14,600, 36,100, and 84,100 pounds were used.

## V TEST RESULTS

A. As indicated in Figure 1, the final CVN 68 configuration delineated in Section III produces satisfactory performance within the limits of the CSV settings shown in Figure 2. A composite graph is shown in Figure 3, which provides a family of curves that indicate the CSV setting required for a specific deadload weight and end speed with a test envelope based on deadload test data.

B. The catapult control parameters established in Section IV were varied during tests in order to clarify the operational limits of the CVN 68 configuration. The results of these tests are described below (NOTE: The results obtained during tests of the standard configuration/conditions were used as a basis of comparison in the discussions and Figures introduced in the following paragraphs):

1. WET-STEAM ACCUMULATOR WATER LEVEL: To determine a satisfactory range of water levels, deadload launches were conducted with 35 and 55 inches of water in the accumulator. The data in Figure 4 discloses no detrimental loss in catapult end speed (variation of 3 knots or less) for the entire CSV range. Figure 5 shows no significant change in peak-to-mean acceleration ratios over the entire 10,500- to 84,100-pound deadload weight range tested.

2. WET-STEAM ACCUMULATOR WATER/STEAM TEMPERATURE DIFFERENTIAL: To determine a satisfactory limit of accumulator water subsaturation temperature differential, two temperature differentials (10 and 15° F) were tested with deadloads weighing 14,600, 35,700, and 84,100 pounds. A temperature differential of 5° F was not tested due to its negligible

effect on catapult performance as stated in reference (b). The data in Figure 6 indicates the temperature differential had no detrimental effect on the peak-to-mean acceleration ratios over the deadload weight range tested. Figure 7 indicates a loss in end speed for all deadload weights with both temperature differentials: 14,600-pound deadload, maximum losses of 5 and 6 knots for 10° F and 15° F differentials respectively; 35,700-pound deadload, maximum losses of 6 and 9 knots at 10° F and 15° F differentials respectively; and 84,100-pound deadload, maximum losses of 5 and 7 knots for 10° F and 15° F differentials respectively.

3. STEAM-PRESSURE CUTOFF-SWITCH LOCATION: Tests were conducted to determine the optimum cutoff-switch location, and to establish a range of locations that would be feasible should the standard cutoff-switch location be inaccessible due to a ship's structural design. Deadloads weighing 10,250/10,500, 35,700/36,100, and 74,300 pounds were used during the tests. With the cutoff switch located at positions 174 and 222 feet forward of catapult station zero, there was no adverse effect on the peak-to-mean ratio as shown in Figure 8, and no significant change in end speed when compared to the standard 210-foot cutoff-switch location as shown in Figure 9. With the 162-foot cutoff-switch location, there was no detrimental effect on the peak-to-mean ratio, but significant losses in end speed, in excess of 3 knots, did occur: the losses were 5 knots with the 10,250/10,500-pound deadloads, and 4 knots with the 35,700/36,100- and 74,300-pound deadloads, as shown in Figure 9. Because the 162-foot cutoff-switch location caused a change in catapult performance, the acceptable range of cutoff-switch locations is from 174 to 222 feet forward of catapult station zero; therefore, the NAVAIRENCEN-selected 210-foot cutoff-switch location is acceptable since it falls within this safe operating range and provides a small amount of steam consumption savings over the maximum switch location of 222 feet from station zero. A greater steam consumption savings could be realized if the switch location was farther aft in the safe operating range.

4. WET-STEAM ACCUMULATOR STEAM PRESSURE: In the event that the required catapult wet-steam accumulator pressure of 520  $\pm$ 5 psig could not be attained, tests were conducted at various wet-steam accumulator pressures to determine their effect on catapult performance. Deadloads weighing 14,600, 36,100, and 84,100/84,400 pounds were launched at steam pressures of 475, 500, 550, and 575 psig. For all deadload weights, increased end speeds resulted with the greater pressures whereas reduced end speeds resulted from the lesser pressures (in comparison with standard 520-psig pressure) (see Figure 10). These effects were more noticeable with the medium-weight and heavyweight deadloads than with the lightweight deadload. For the heavyweight deadloads at the higher CSV settings (worse condition), the variation in end speed was less than 6 knots between the standard pressure (520 psig) and either the 500- or the 550-psig events. Interpolation of this data indicates that there would be an end-speed spread of less than  $\pm$ 3 knots (which is considered insignificant) with

a steam-pressure differential of  $\pm 10$  psig from the standard of 520 psig. When operating the Leslie control system in the automatic or manual mode, a pressure differential of  $\pm 5$  psig can be easily maintained. The steam-pressure variations had no adverse effect on peak-to-mean acceleration characteristics as depicted in Figure 11.

5. HYDRAULIC-SYSTEM SUPPLY PRESSURE: To evaluate the effect of various hydraulic-system pressures on catapult performance, tests were conducted with deadloads weighing 14,600, 36,100, and 84,100 pounds using hydraulic pressures of 2,200, 2,400, 2,600, and 2,700 psig. For all deadload weights, the 2,200- and 2,700-psig pressures caused the following significant variances in end speeds as shown in Figure 12: 14,600-pound deadload, a nominal variation of 5 knots; 36,100-pound deadload, variations of 4 and 3 knots with 2,200- and 2,700-psig pressures respectively; and 84,100-pound deadload, variations of 4 and less than 2 (considered insignificant) knots with 2,200- and 2,700-psig pressures respectively. For all deadload weights, the end-speed variations were insignificant (less than 3 knots) with the 2,400- and 2,600-psig pressures as shown in Figure 12. The various hydraulic-system pressures had no detrimental effect on the peak-to-mean acceleration ratio curves as shown in Figure 13.

## VI ANALYSIS OF TEST RESULTS

A. The design of the CVN 68 control-system components is tolerant of small variations in the operating configuration. The test results of Section V establish a range of limits beyond those set forth in Section IVA in which the catapult components can be operated with no adverse effect on catapult performance.

B. The CVN 68 control-system design suitability is such that control-system variation can be maintained at a tighter tolerance. During this report period, on-site military personnel had no difficulty in maintaining control-system parameters using the tolerances established in Section IVA.

## VII CONCLUSIONS

A. The final catapult configuration (see Section III) for the CVN 68 class vessels produces satisfactory catapult performance, provided the events are contained within the test envelope shown in Figure 3 and the peak longitudinal accelerations correspond to the values shown in Figure 1. (Section V, Paragraph A)

B. The limits listed below are the expanded limits determined by the test results in Section V. These limits are the maximum for which no adverse effect on catapult performance occurred:

1. A maximum wet-steam accumulator water subsaturation temperature differential of 5° F. (Section V, Paragraph B2)
2. Hydraulic-system supply pressure of 2,500  $\pm$ 100 psig. (Section V, Paragraph B5)
3. Wet-steam accumulator steam pressure of 520  $\pm$ 10 psig. (Section V, Paragraph B4)
4. Wet-steam accumulator water-level range of 35 to 55 inches. (Section V, Paragraph B1)
5. Steam-pressure cutoff-switch located 174 to 222 feet from catapult station zero. (Section V, Paragraph B3)

C. The catapult control-system parameters established in Section IVA can be easily maintained by catapult operational personnel due to the design effectiveness of the CVN 68 control system, as discussed in Section VI. With the tighter control-system tolerances readily attainable with no adverse effect on catapult readiness, it is concluded that the limits listed below for catapult control-system parameters could be maintained:

1. Maximum wet-steam accumulator water subsaturation temperature differential of 5° F.
2. Hydraulic-system supply pressure of 2,500  $\pm$ 50 psig.
3. Wet-steam accumulator steam pressure of 520  $\pm$ 5 psig.
4. Wet-steam accumulator water-level range of 50  $\pm$ 2 inches.
5. Steam-pressure cutoff-switch located 210 feet from catapult station zero; however, greater steam consumption savings could be obtained by moving the cutoff-switch location aft in the safe operating range.

### VIII RECOMMENDATIONS

A. Incorporate the finalized configuration delineated in Section III on the catapults of the CVN 68 class vessels. (This configuration has already been incorporated on the USS NIMITZ (CVN 68).)

B. The following catapult operational limits should be maintained on the CVN 68 class vessels (already adhered to on the CVN 68):

1. Maximum wet-steam accumulator water subsaturation temperature differential of 5° F.

2. Hydraulic-system supply pressure of 2,500  $\pm$  50 psig.

3. Wet-steam accumulator steam pressure of 520  $\pm$  5 psig.

4. Wet-steam accumulator water-level range of 50  $\pm$  2 inches.

5. Steam-pressure cutoff-switch located 210 feet from catapult station zero.

C. The NAVAIRENGCEN should review the cutoff-switch locations and, if warranted, move it aft to effect a savings in steam consumption.

### IX REFERENCES

- (a) NAVAIRTESTFAC Report No. NATF-EN-1117 of 22 Dec 1971: Initial Evaluation of Integrated Catapult Control Station and Associated Catapult Equipment for the CVN 68
- (b) NAVAIRTESTFAC Letter Report No. NATF-L75 of 21 Oct 1970: Evaluation of the final catapult configuration for the USS MIDWAY (CV 41)

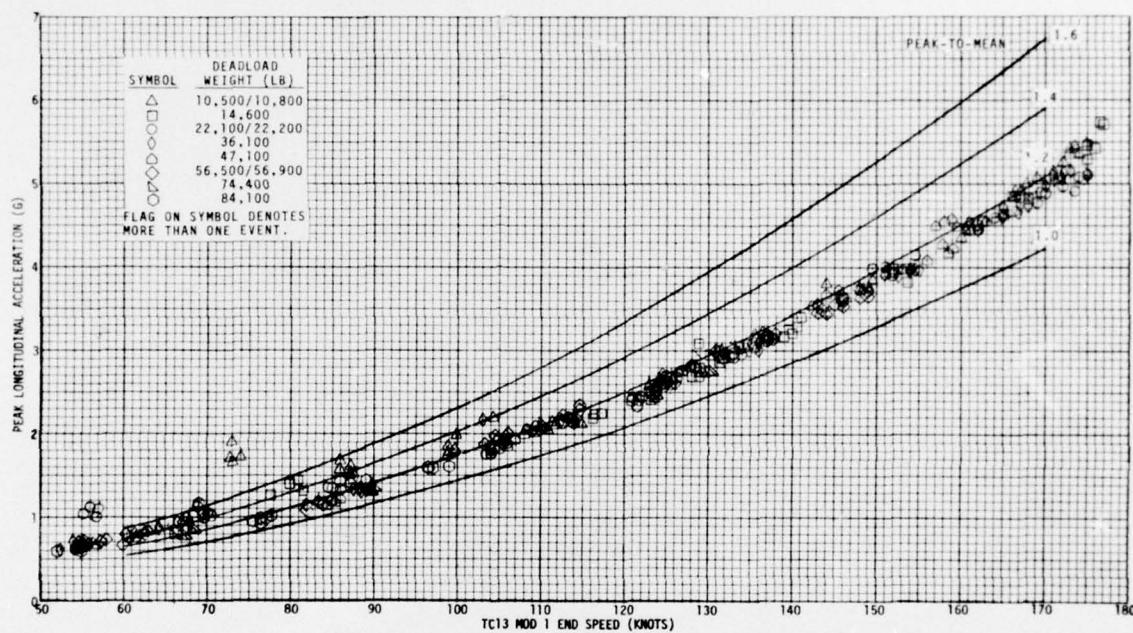


FIGURE 1 - COMPOSITE GRAPH OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1 END SPEED; STANDARD CVN 68 CATAPULT CONFIGURATION

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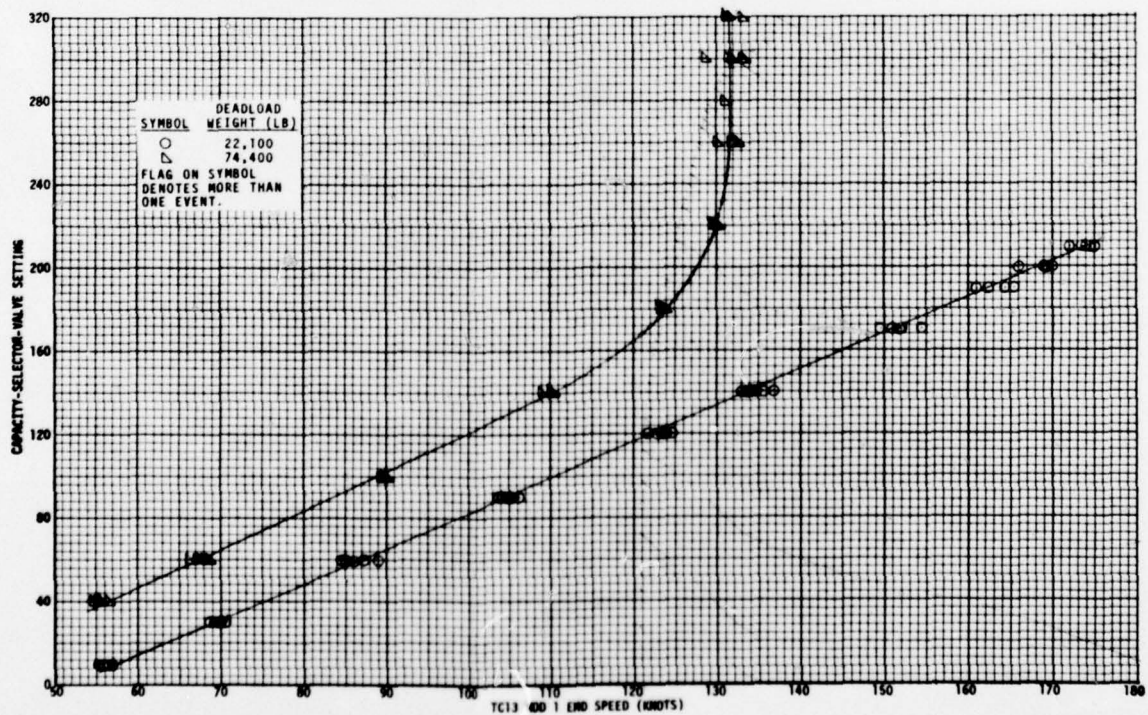
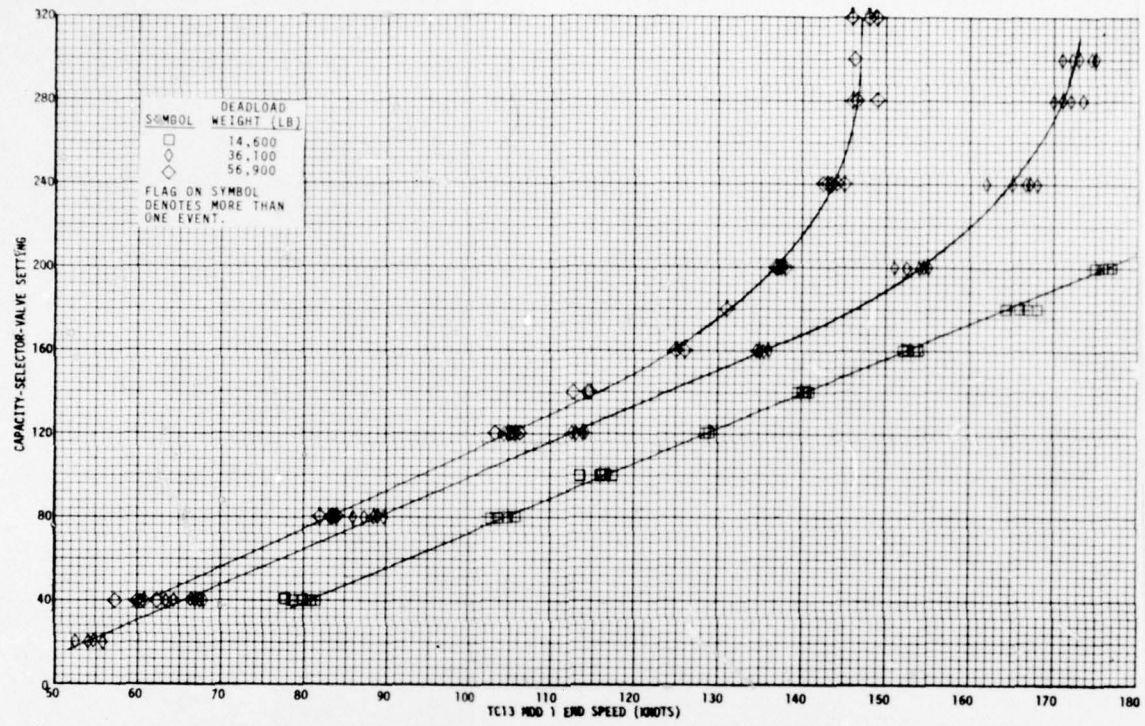


FIGURE 2 -

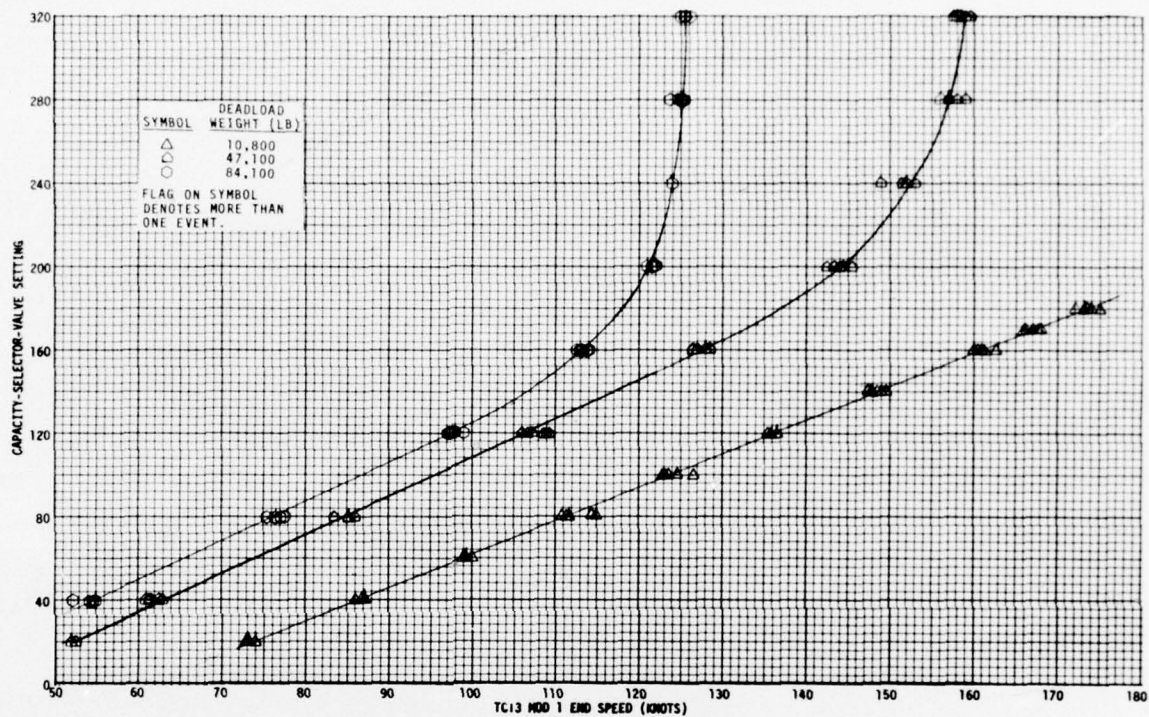


FIGURE 2 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1 END SPEED; STANDARD CVN 68 CATAPULT CONFIGURATION

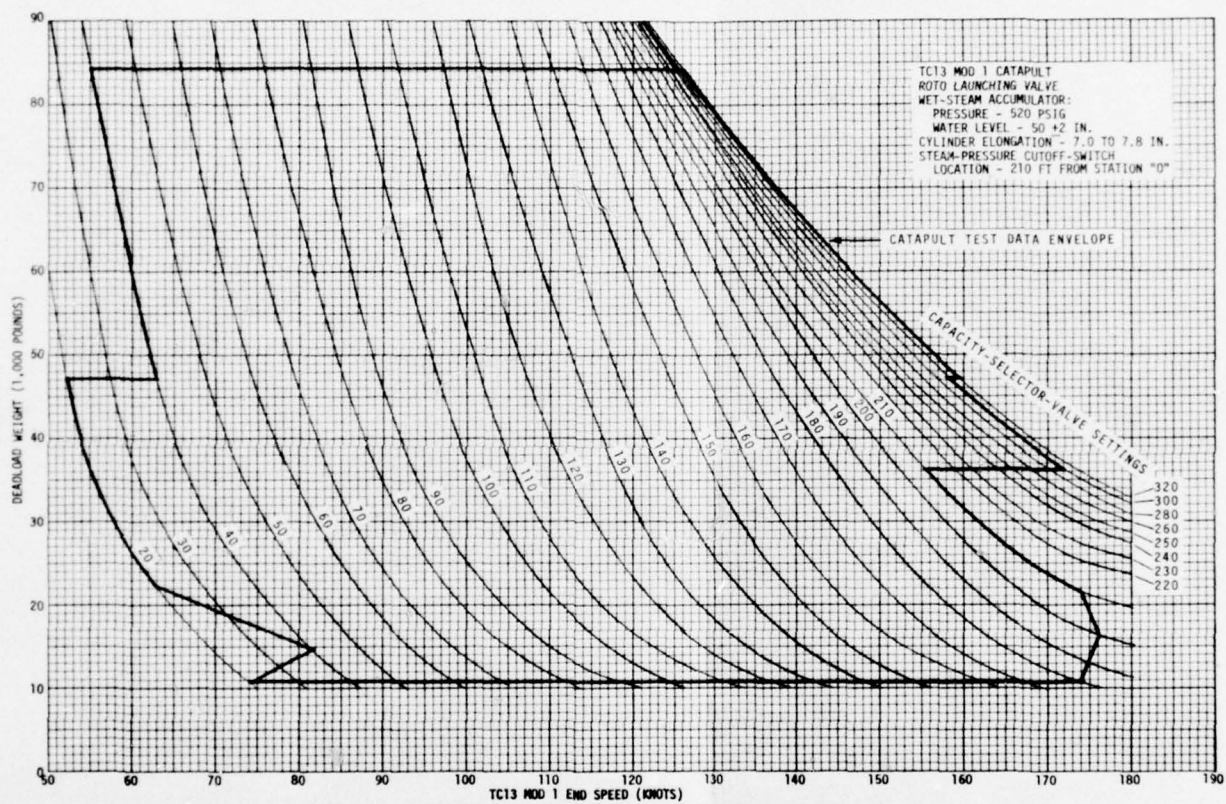


FIGURE 3 - PERFORMANCE ENVELOPE OF DEADLOAD WEIGHT VERSUS TC13 MOD 1  
 END SPEED; STANDARD CVN 68 CATAPULT CONFIGURATION

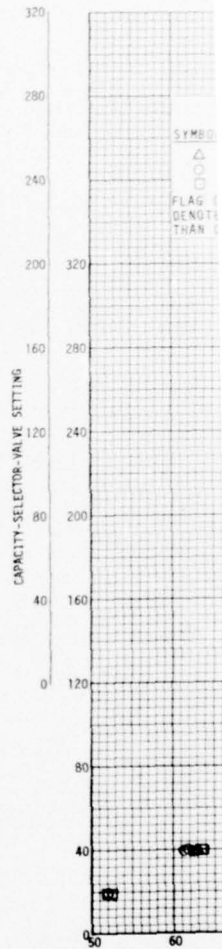
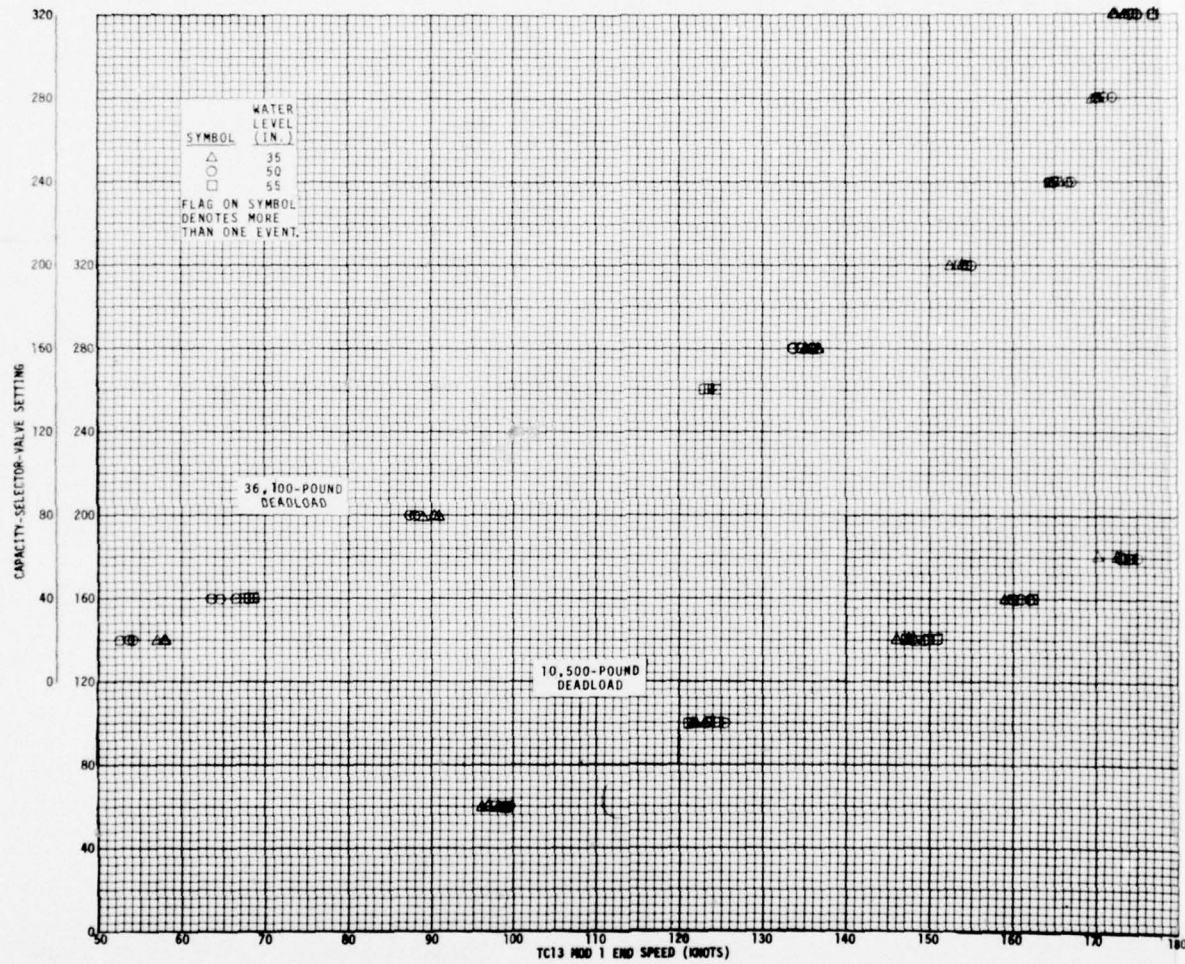
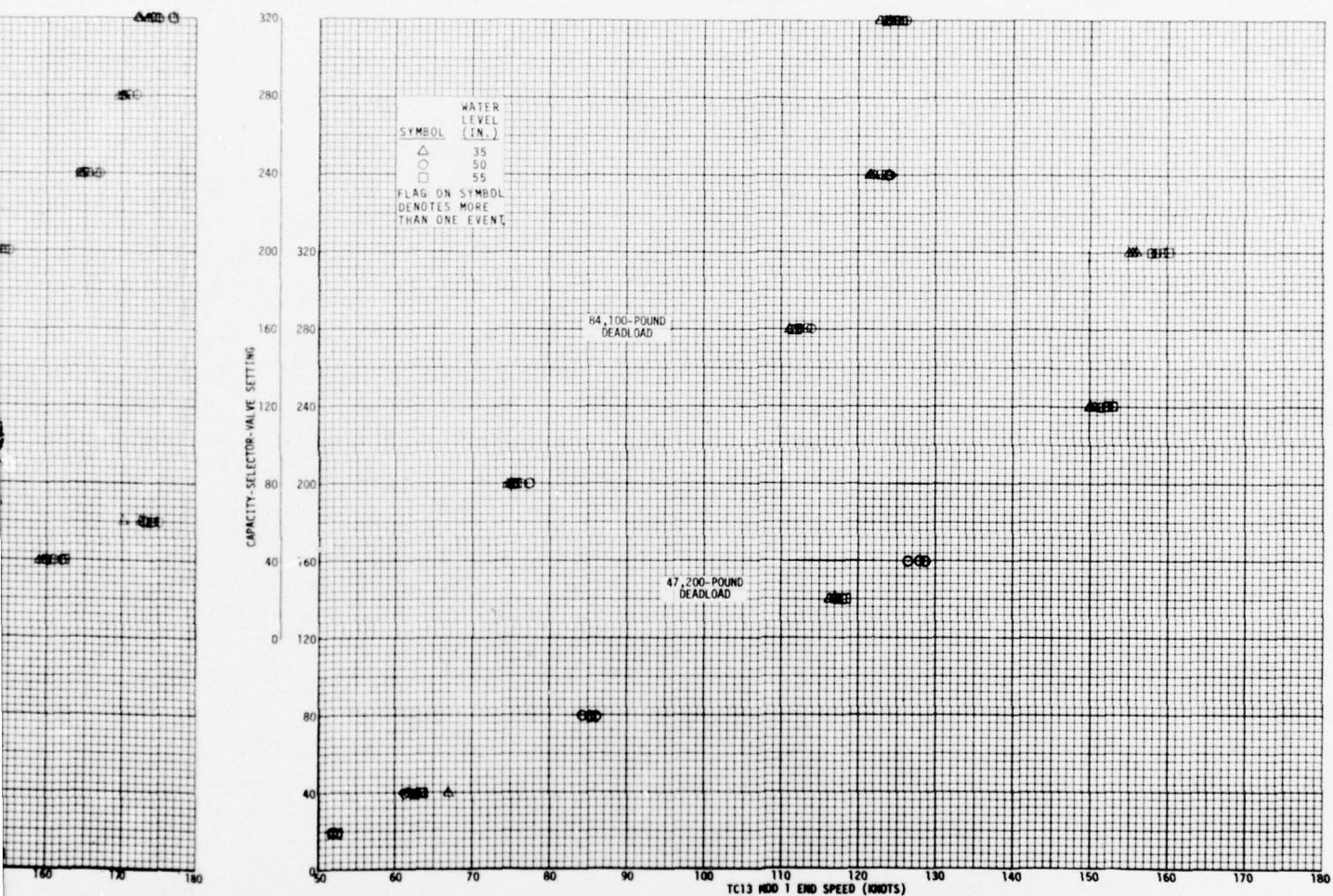
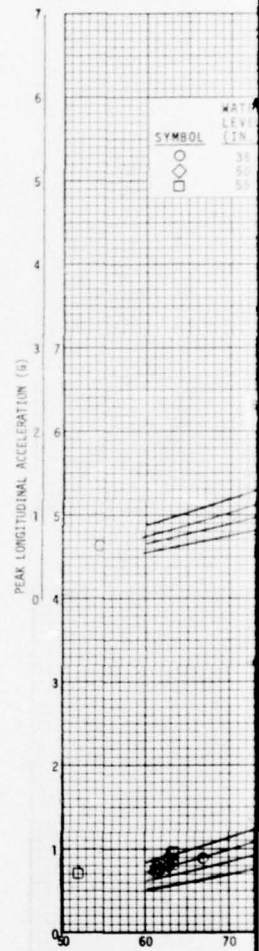
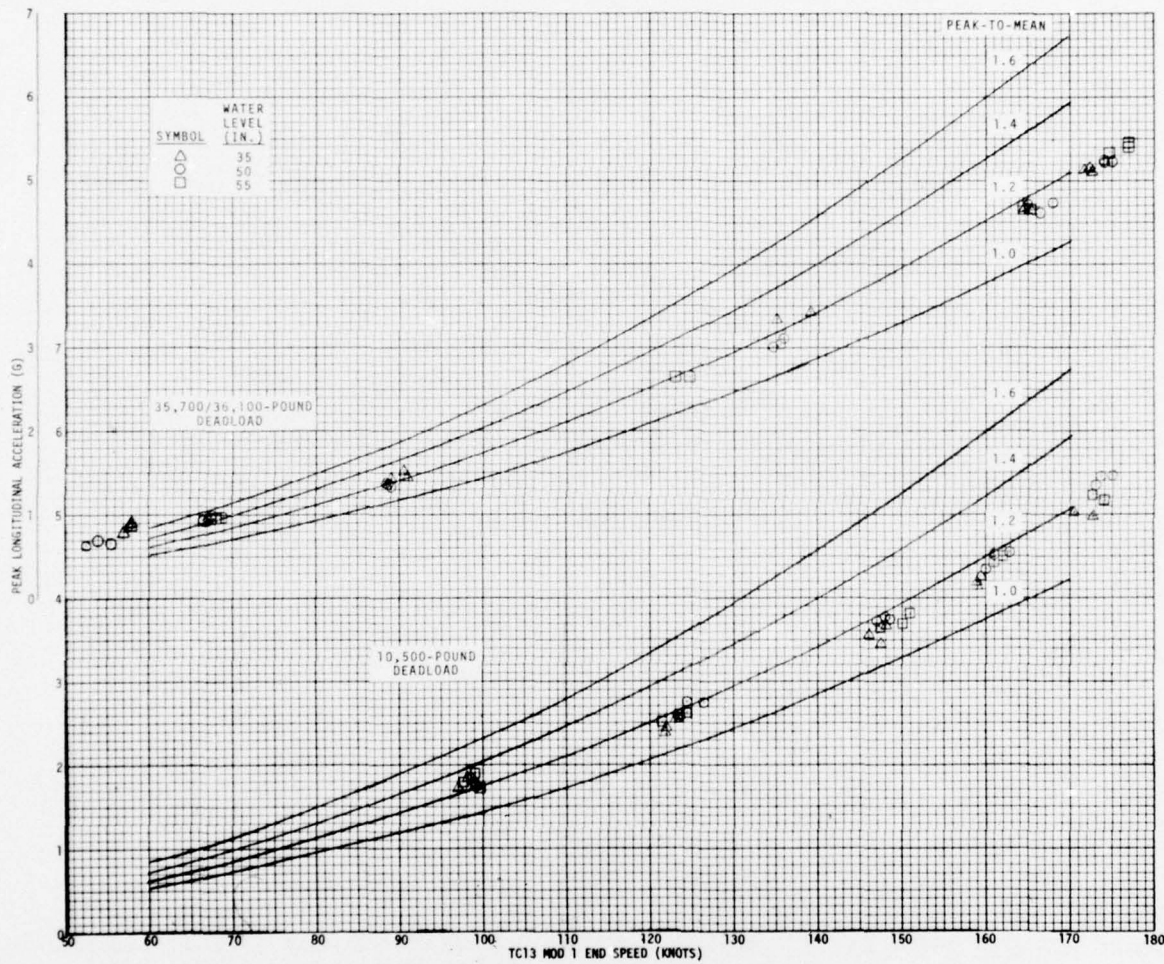


FIGURE 4 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING vs. END SPEED; VARIED WET-STEAM ACCUMULATOR (CVN 68 CATAPULT/DEADLOAD CALIBRATION)



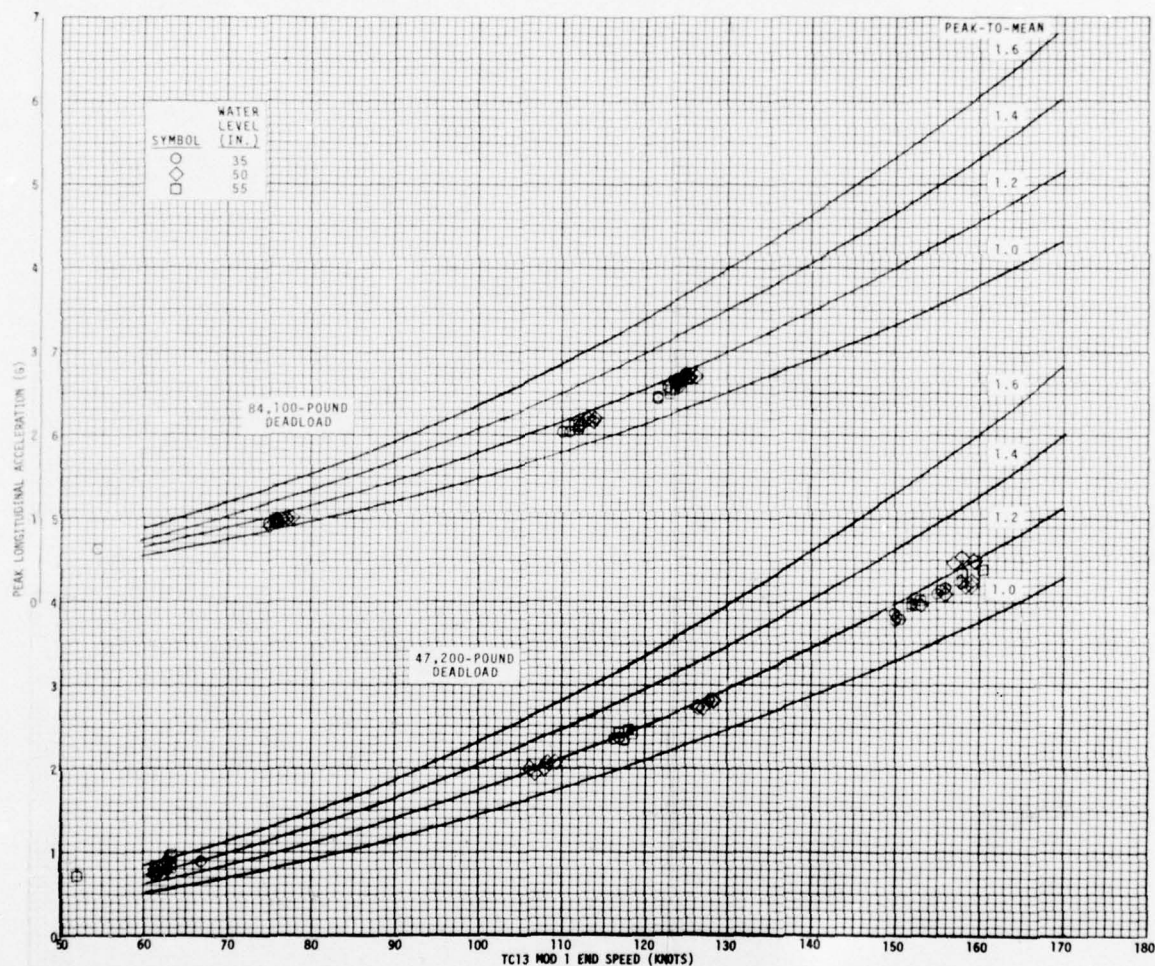
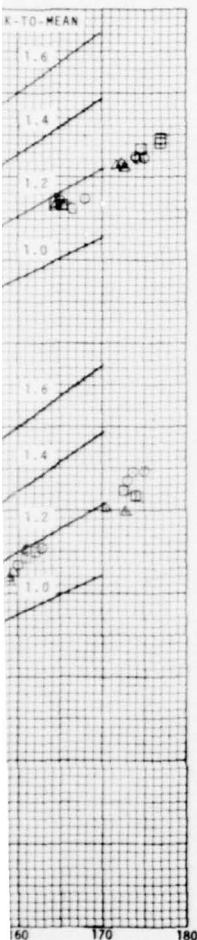
PHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1  
 SPEED; VARIED WET-STEAM ACCUMULATOR WATER LEVELS  
 (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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NOTE: FLAG ON SYMBOL DENOTES MORE THAN ONE EVENT.

FIGURE 5 - COMPOSITE GRAPHS OF PEAK LONGITUDINAL ACCELERATION  
END SPEED; VARIED WET-STEAM ACCUMULATOR W  
(CVN 68 CATAPULT/DEADLOAD CALIBRATION)



ENOTES MORE THAN ONE EVENT.

APHS OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1  
SPEED; VARIED WET-STEAM ACCUMULATOR WATER LEVELS  
(CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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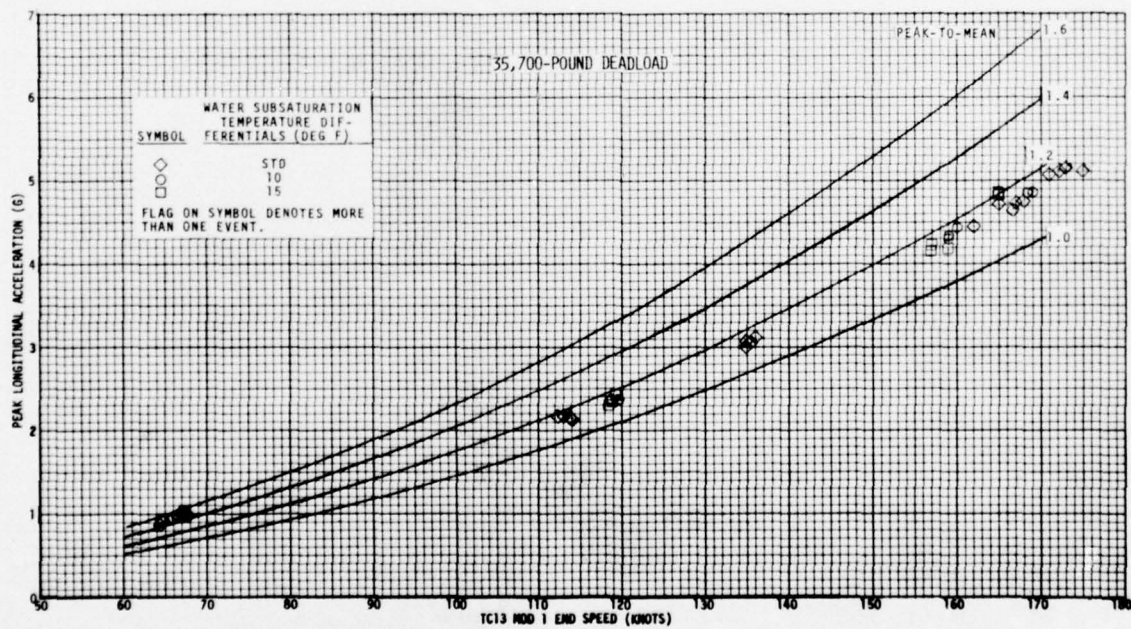
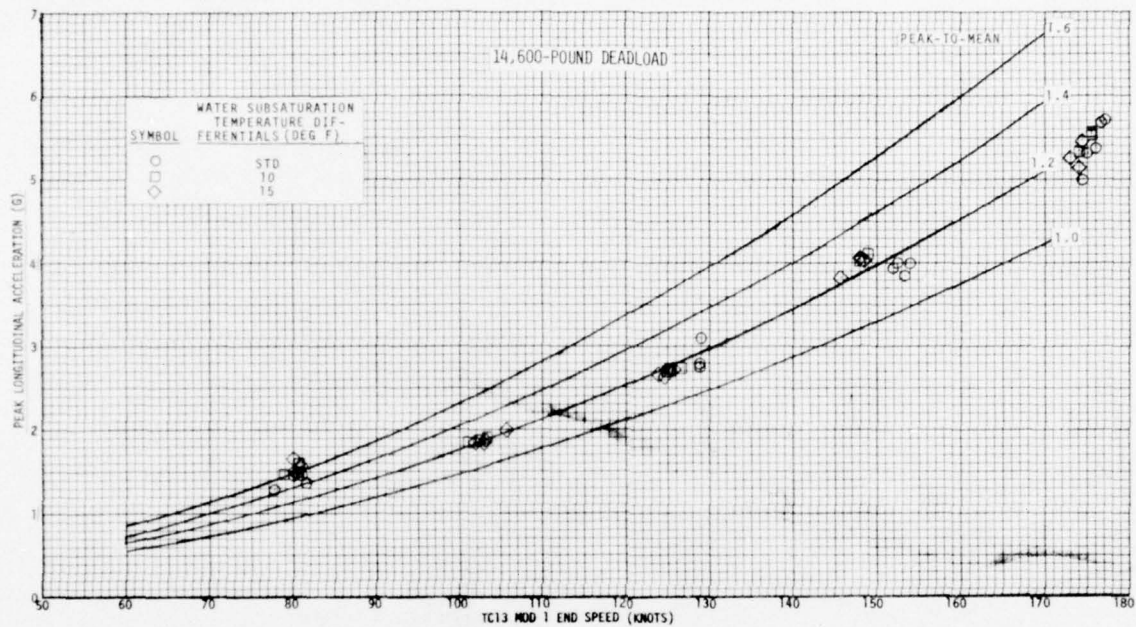


FIGURE 6 - CON

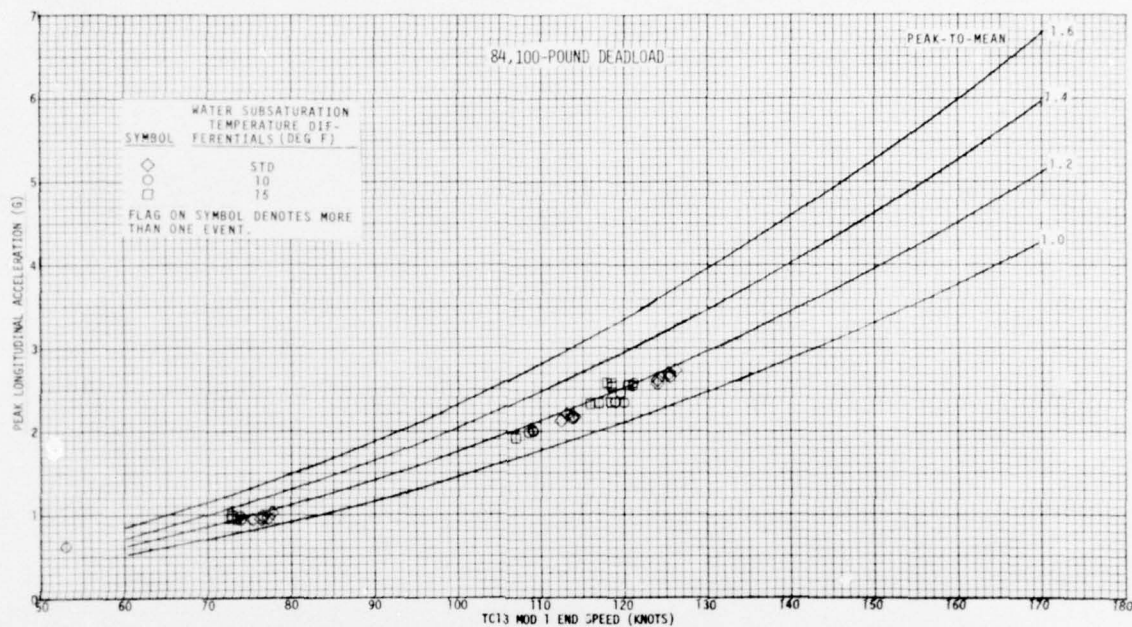
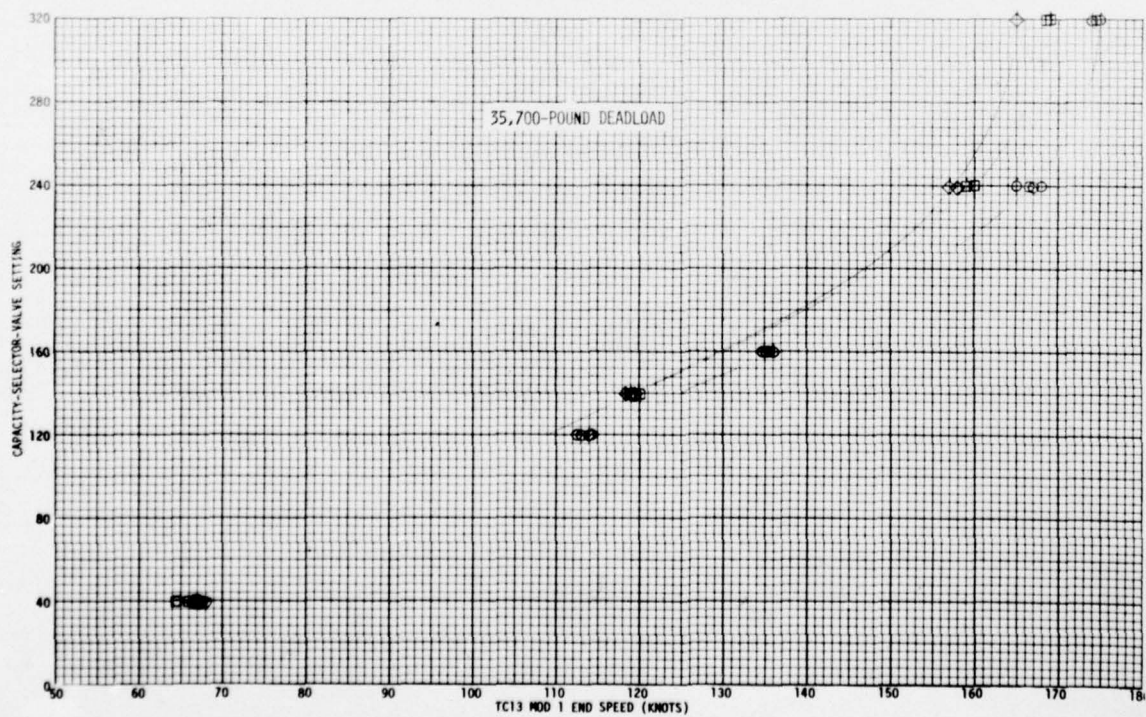
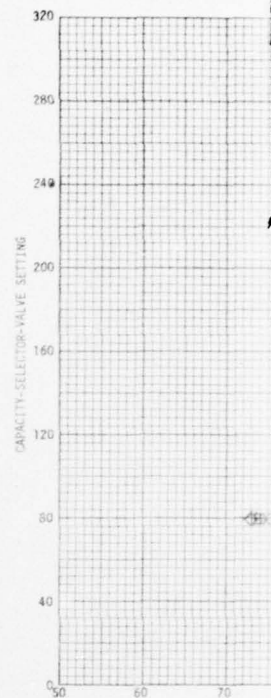
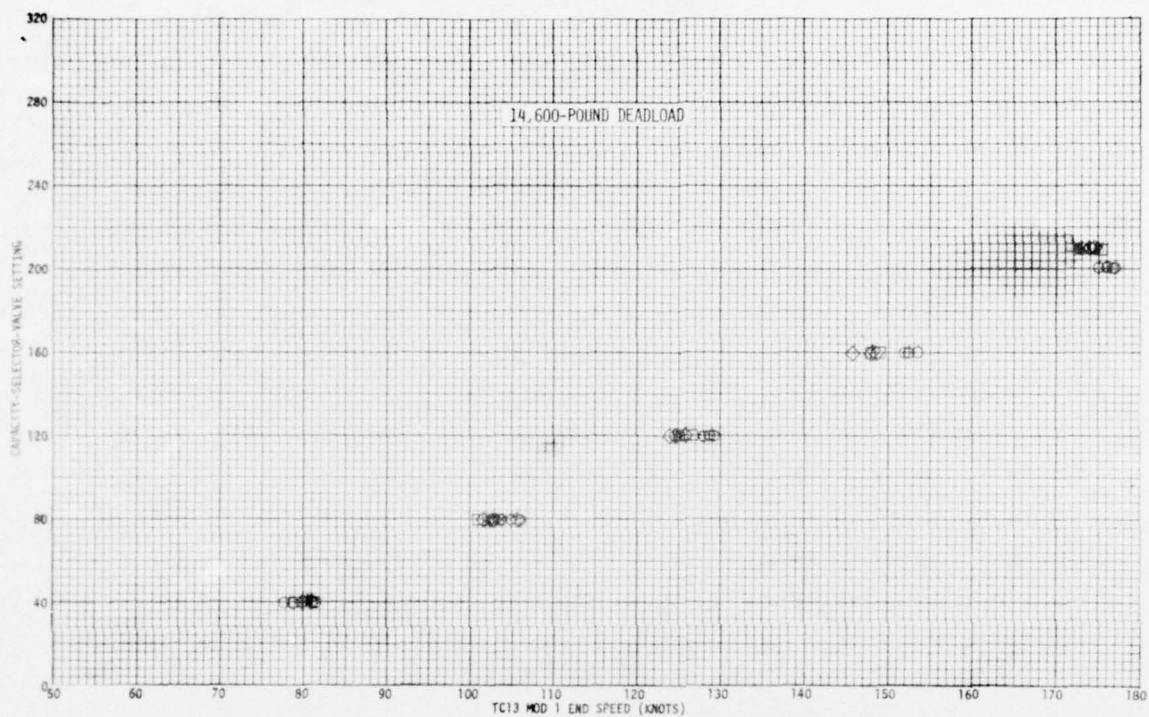


FIGURE 6 - COMPOSITE GRAPHS OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1 END SPEED; VARIED WATER SUBSATURATION TEMPERATURE DIFFERENTIALS (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)



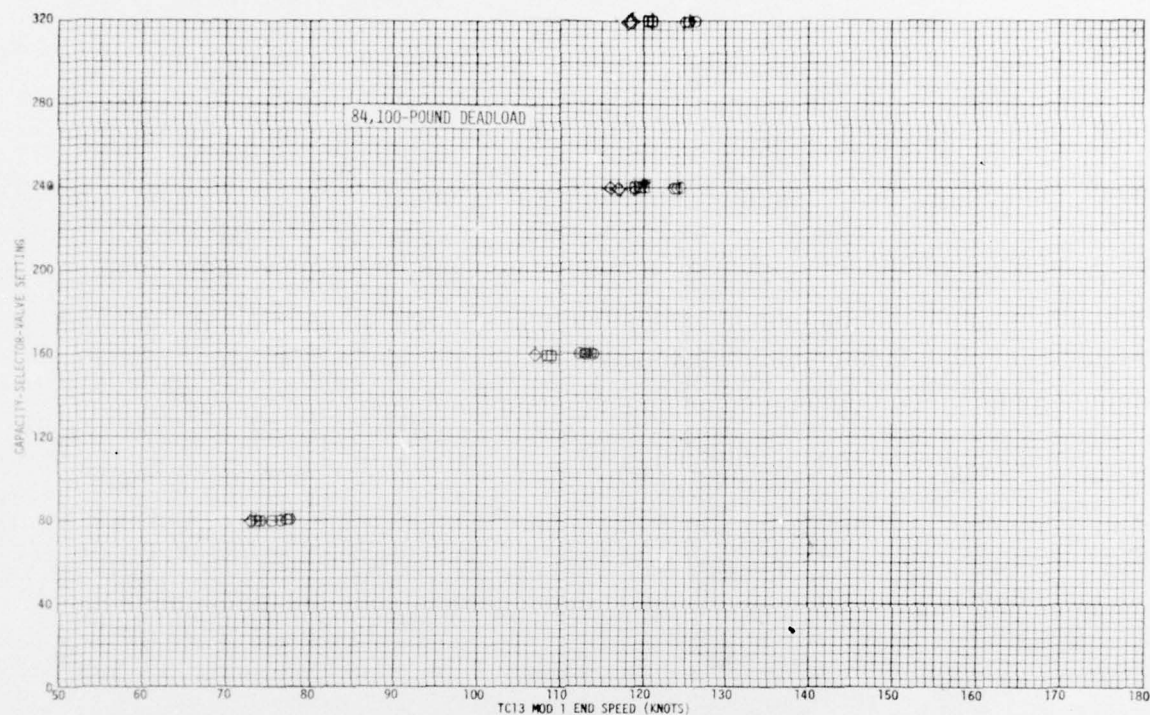
WATER SUBST  
TEMPERATUR  
FERENTIALS

SYMBOL

○ STD  
□ 10  
◇ 15

FLAG ON SYMBOL DENOT  
THAN ONE EVENT.

FIGURE 7 - COMPOSITE  
END SPEED



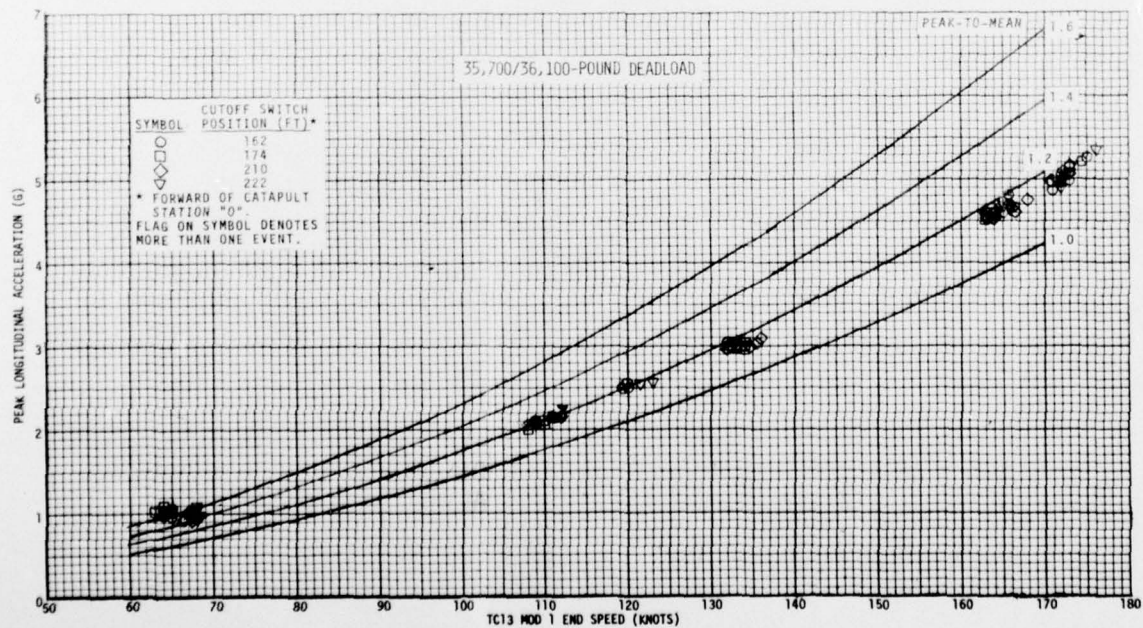
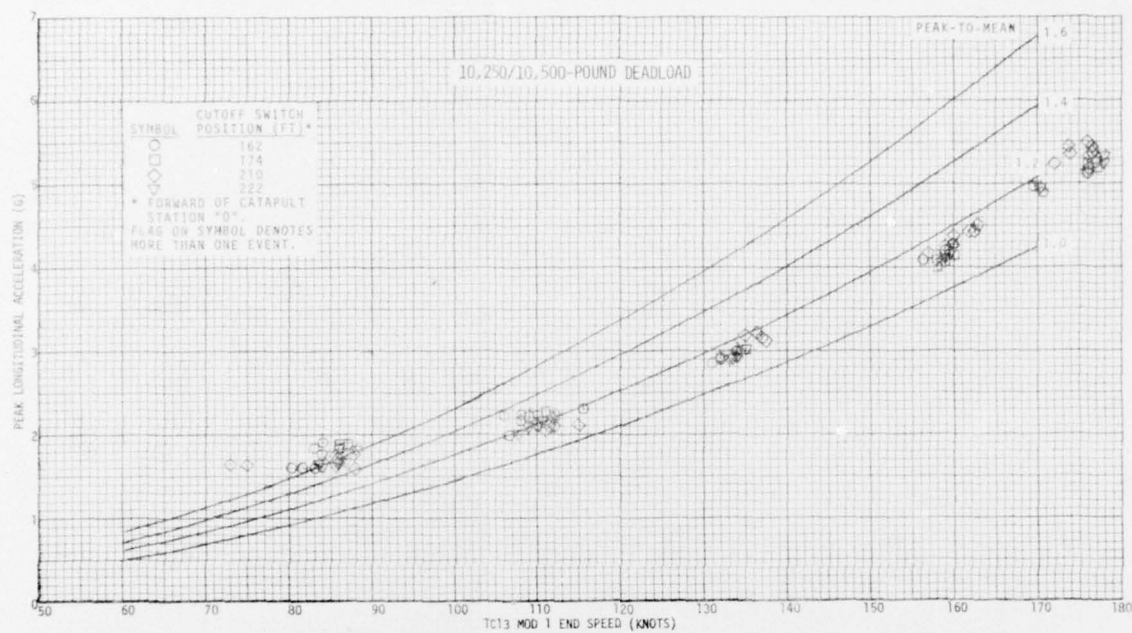
WATER SUBSATURATION  
TEMPERATURE DIF-  
FERENTIALS (DEG F)

SYMBOL	TEMPERATURE DIF- FERENTIALS (DEG F)
○	STD
□	10
◇	15

FLAG ON SYMBOL DENOTES MORE  
THAN ONE EVENT.

FIGURE 7 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1  
END SPEED; VARIED WATER SUBSATURATION TEMPERATURE DIFFERENTIALS  
(CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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FIG

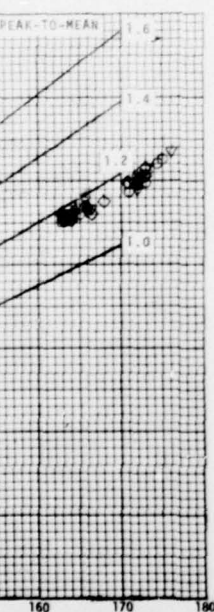
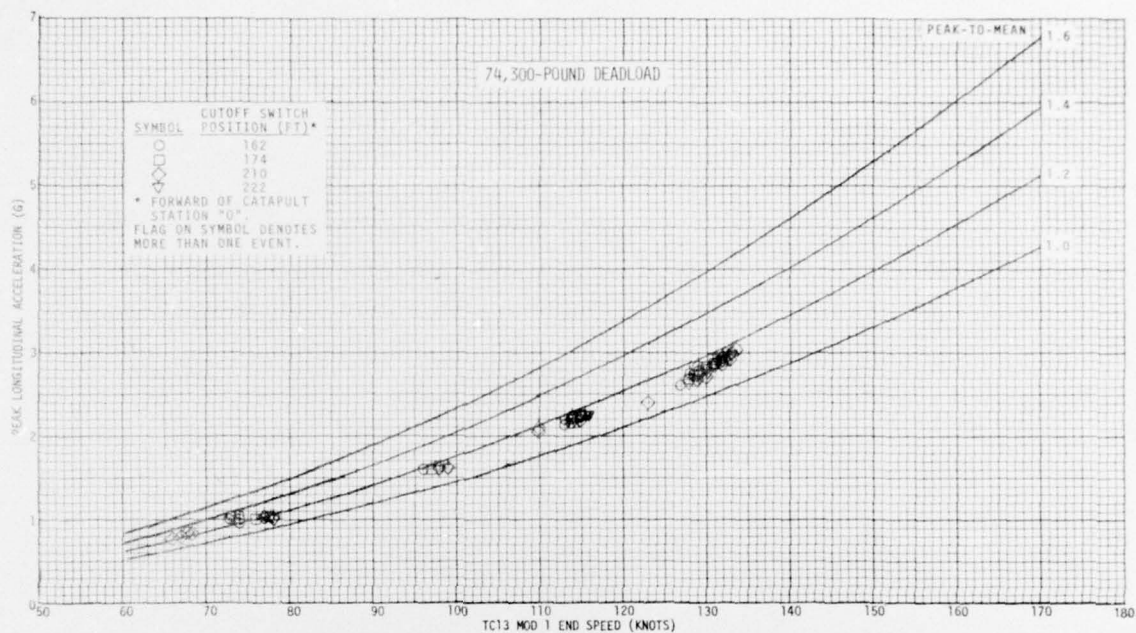
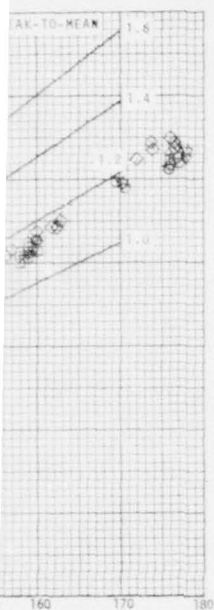
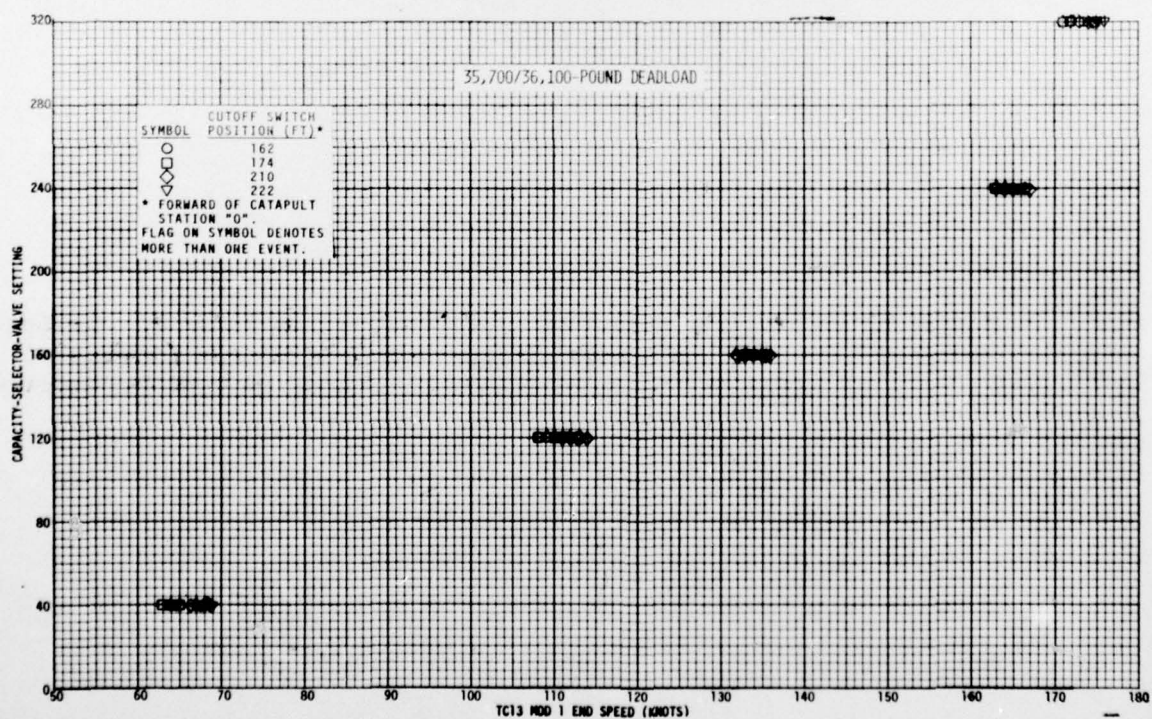
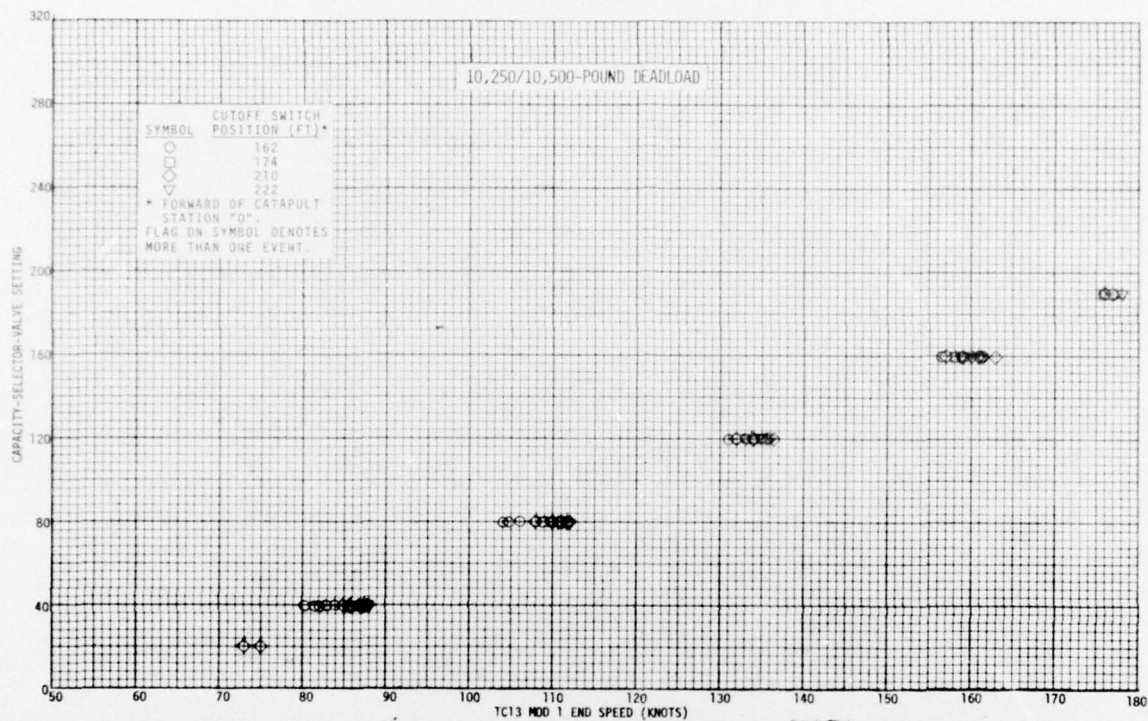


FIGURE 8 - COMPOSITE GRAPHS OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1 END SPEED; VARIED STEAM-PRESSURE CUTOFF-SWITCH LOCATIONS (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

*[Handwritten signature]*



FIGURE

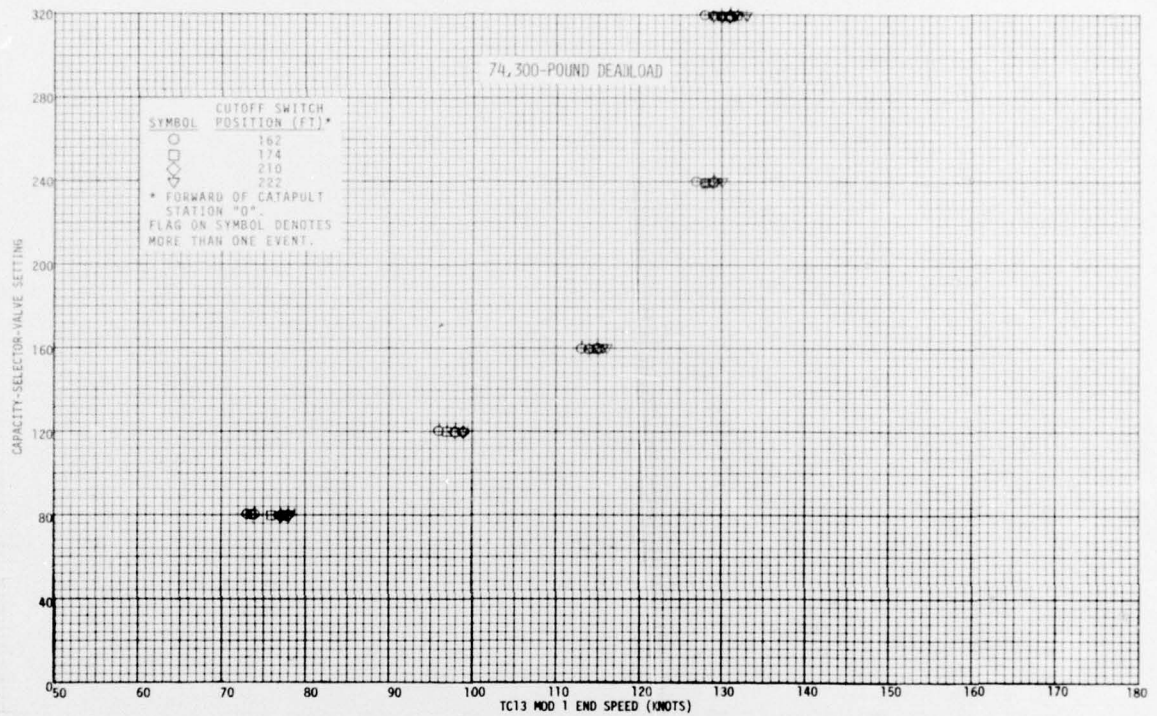
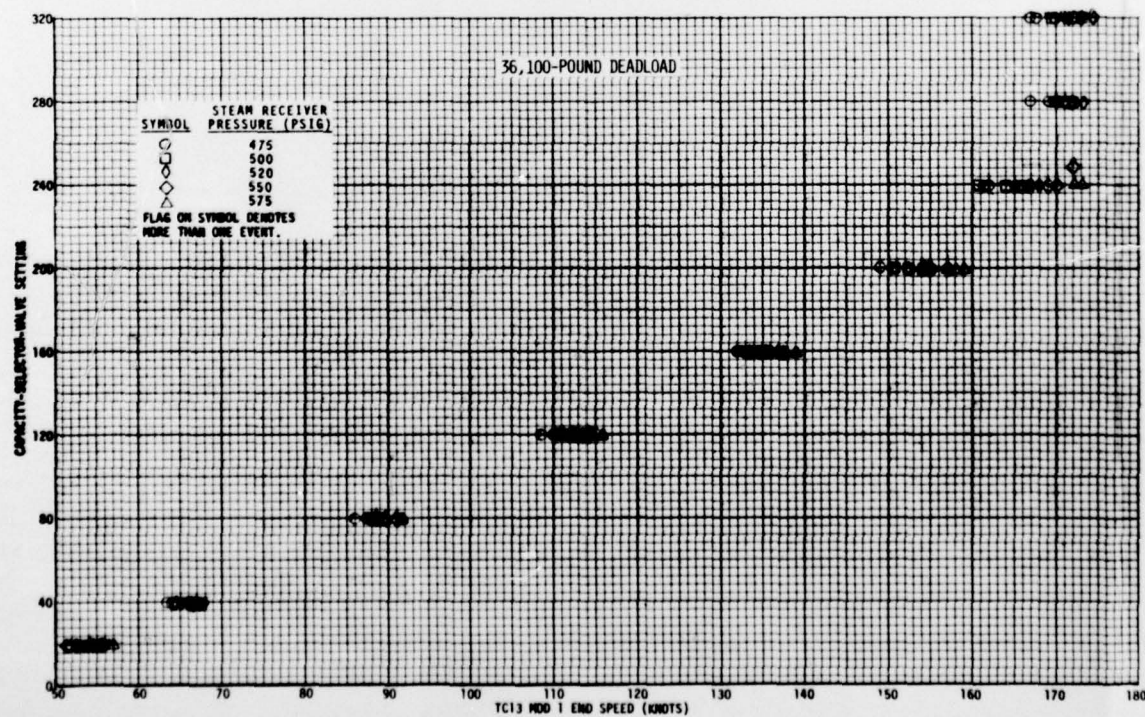
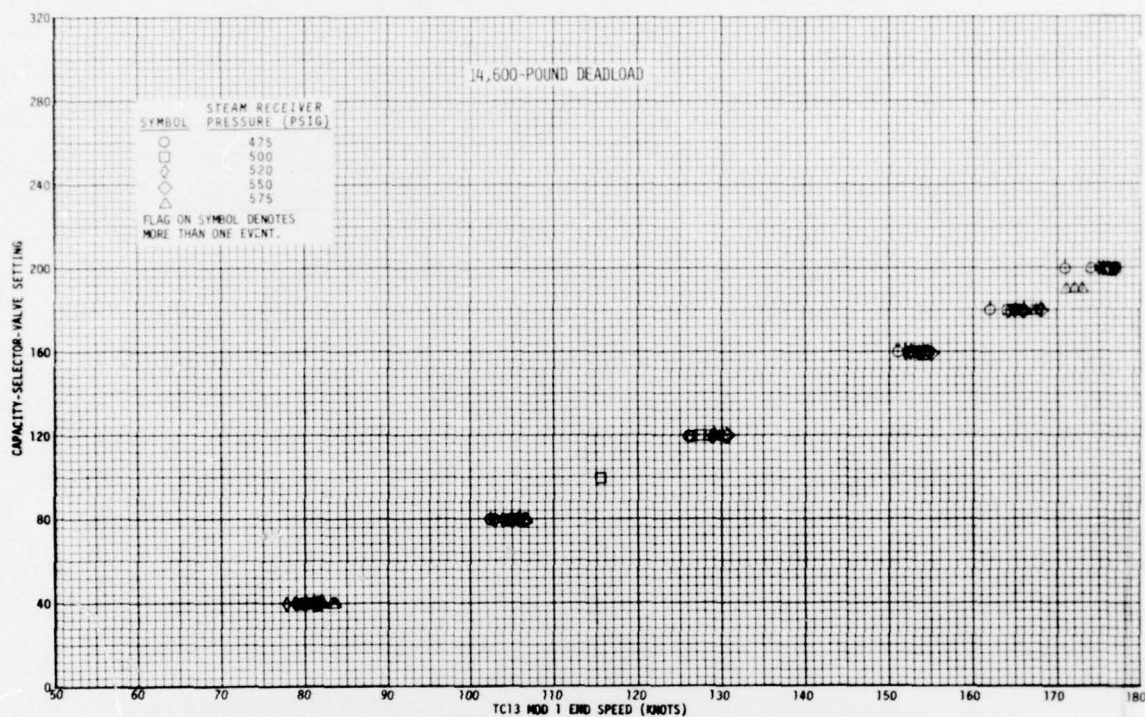


FIGURE 9 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1 END SPEED; VARIED STEAM-PRESSURE CUTOFF-SWITCH LOCATIONS (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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FIG

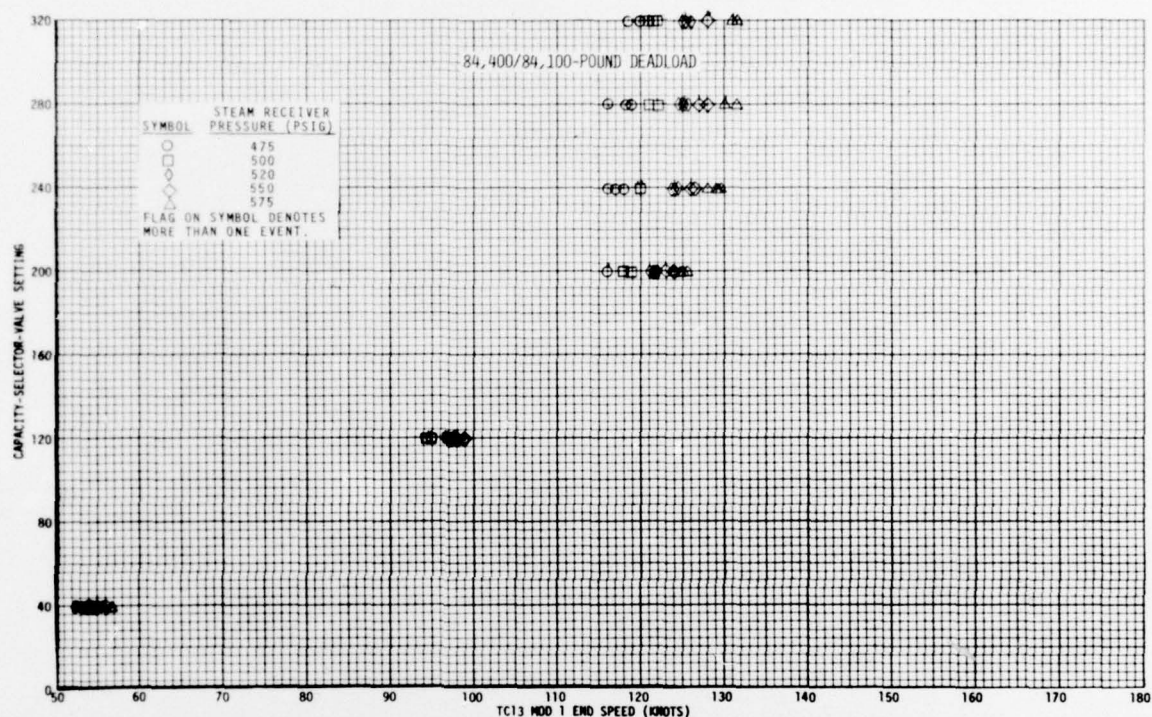
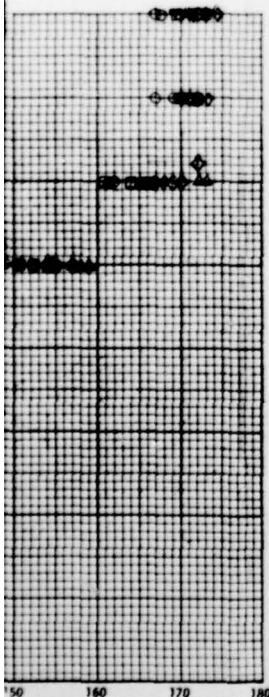
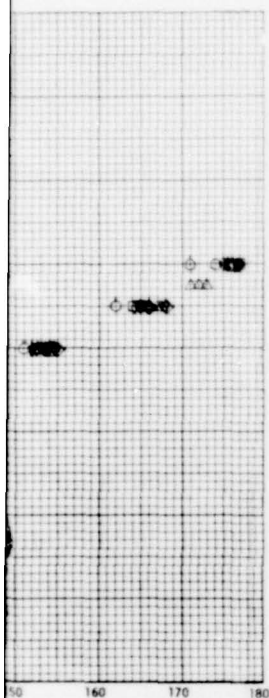
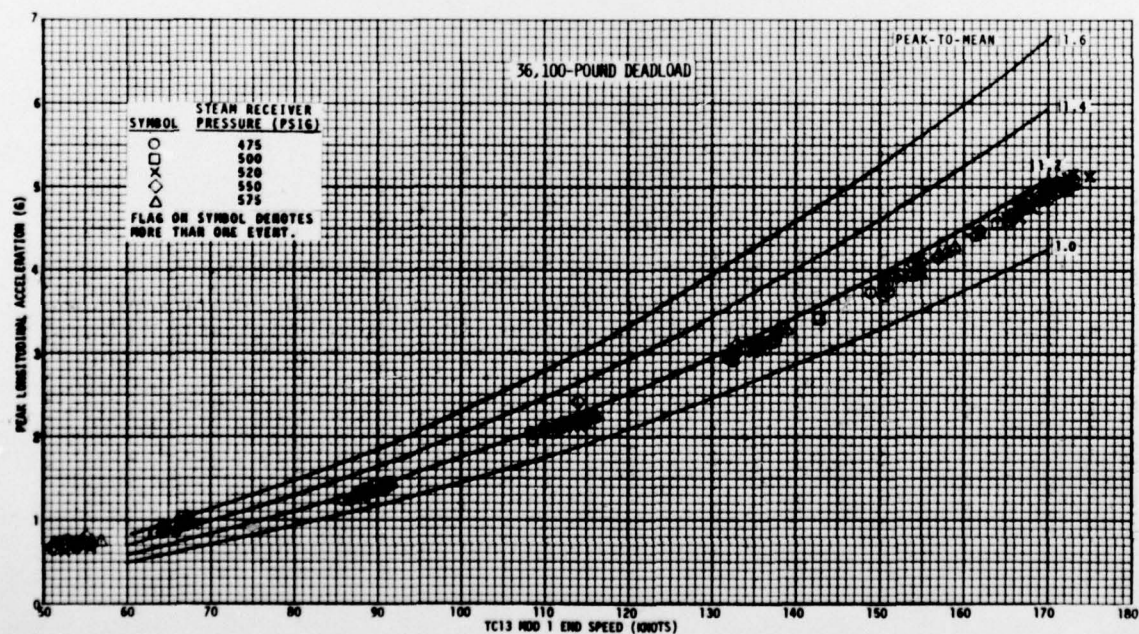
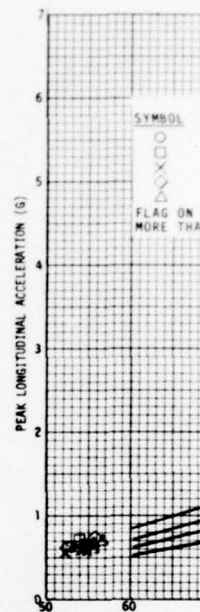
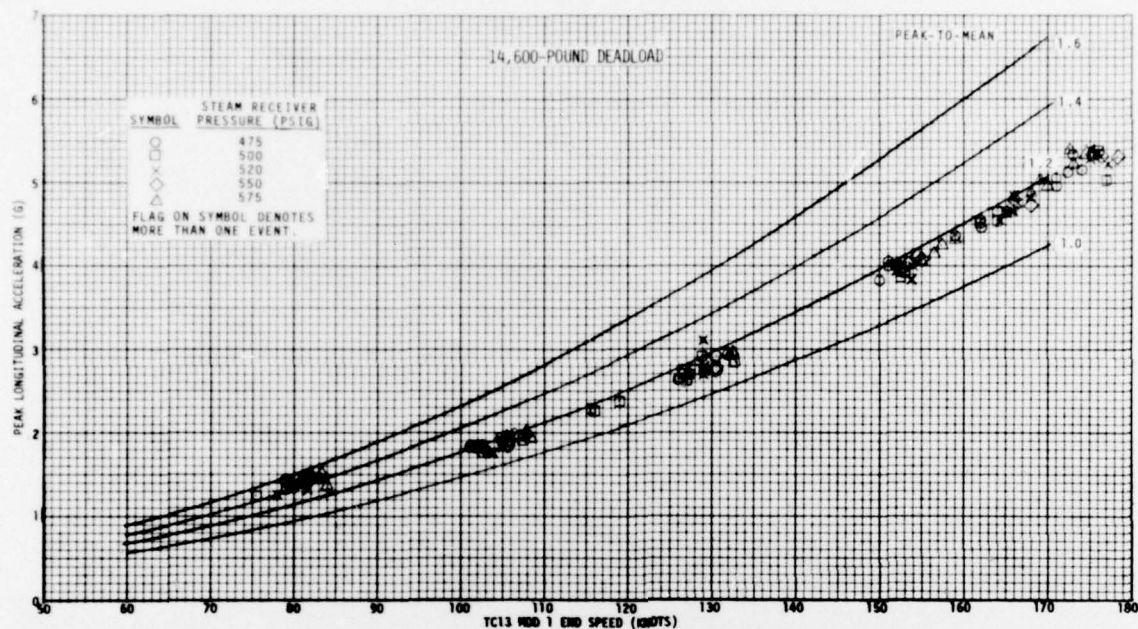


FIGURE 10 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1 END SPEED; VARIED WET-STEAM ACCUMULATOR PRESSURES (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)



FIGURE

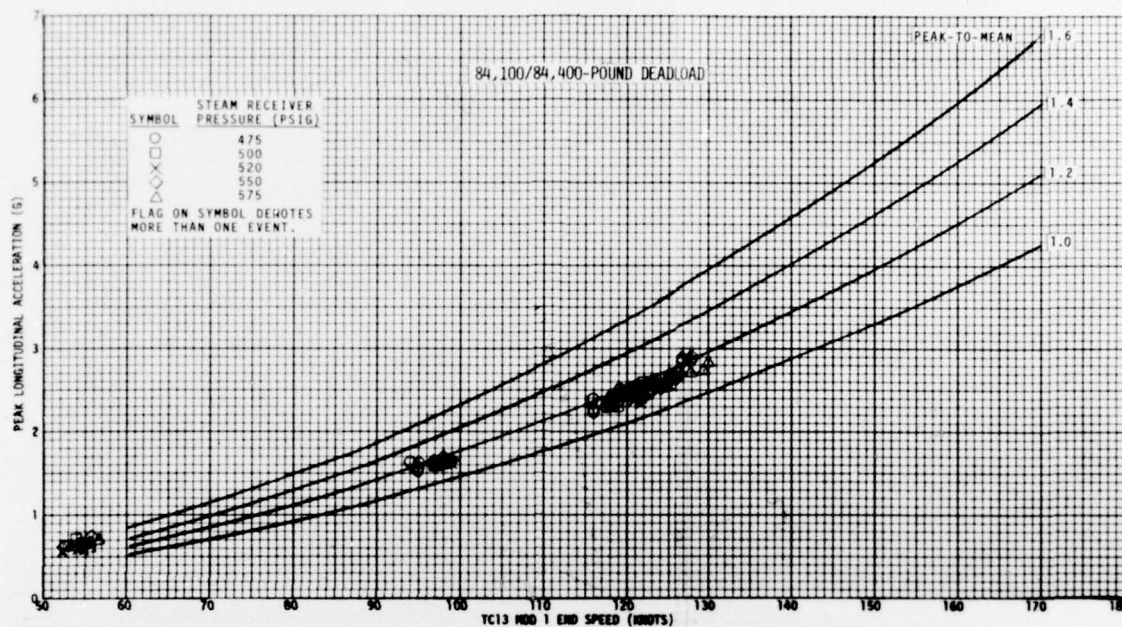
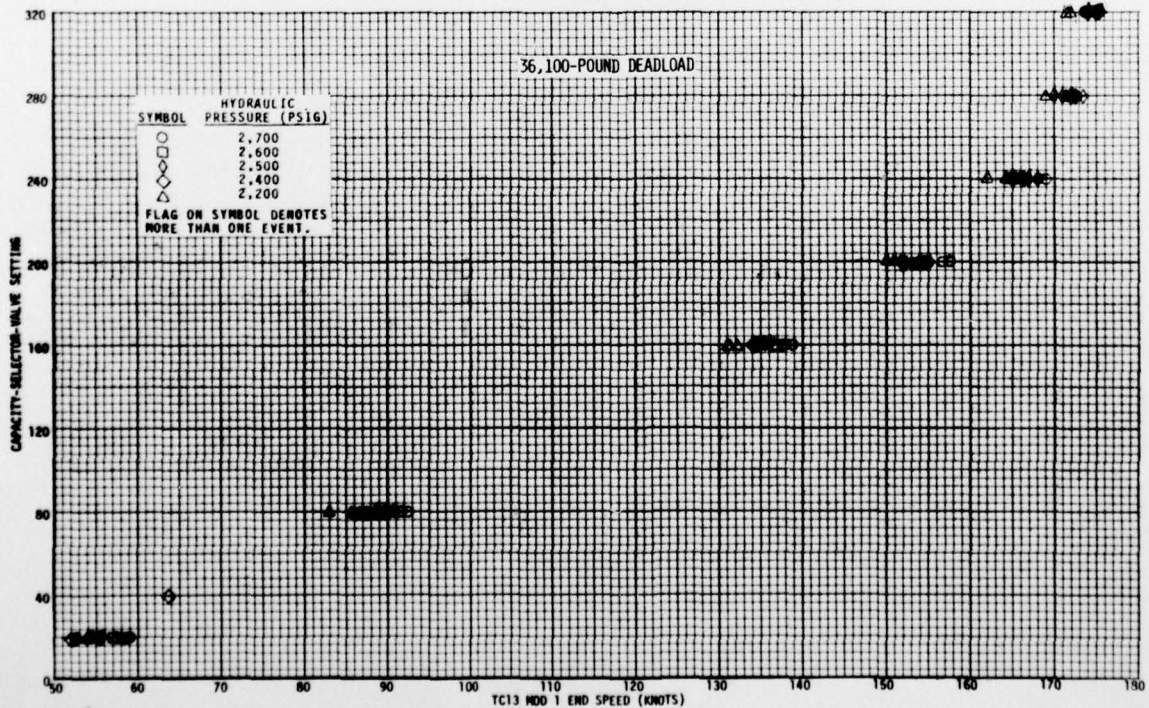
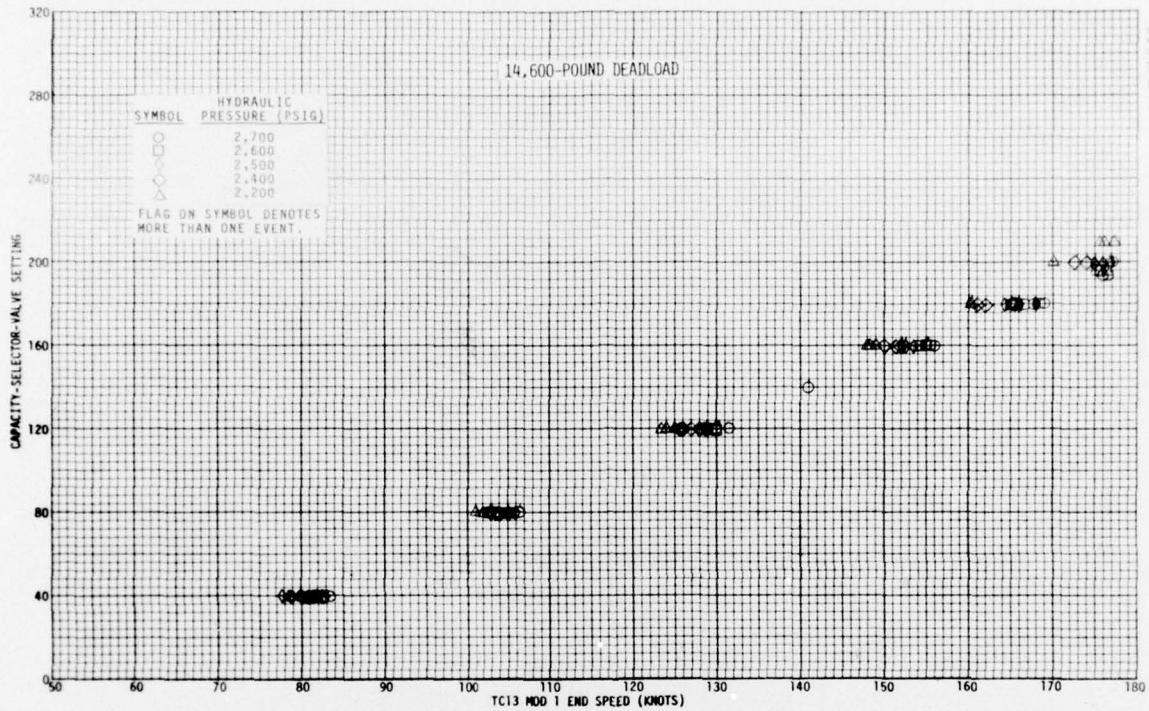


FIGURE 11 - COMPOSITE GRAPHS OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1 END SPEED; VARIED WET-STEAM ACCUMULATOR PRESSURES (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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FIGURE

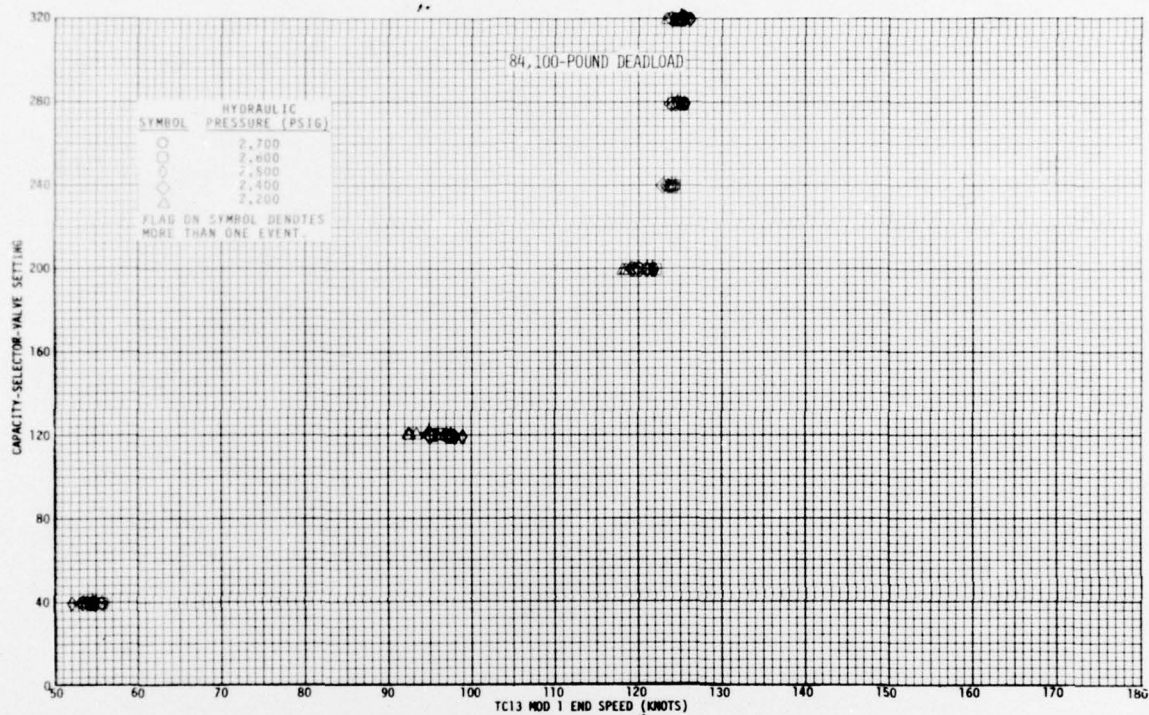
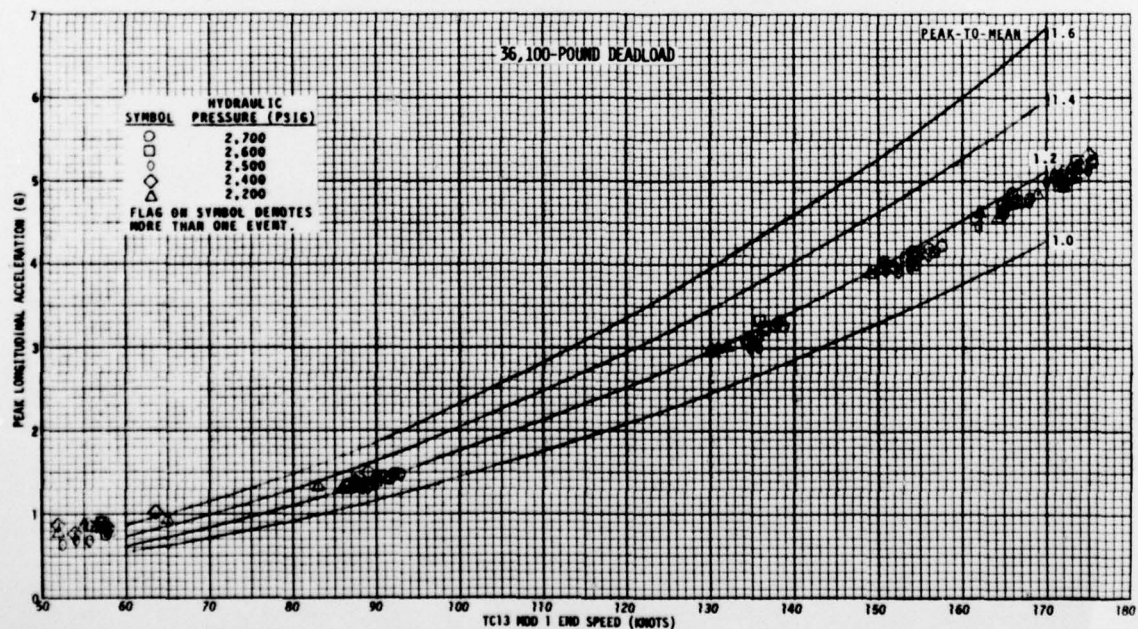
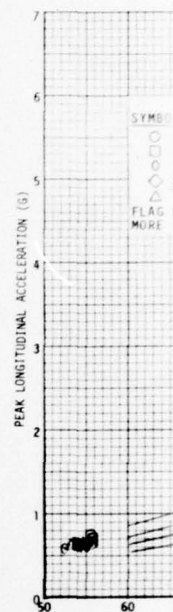
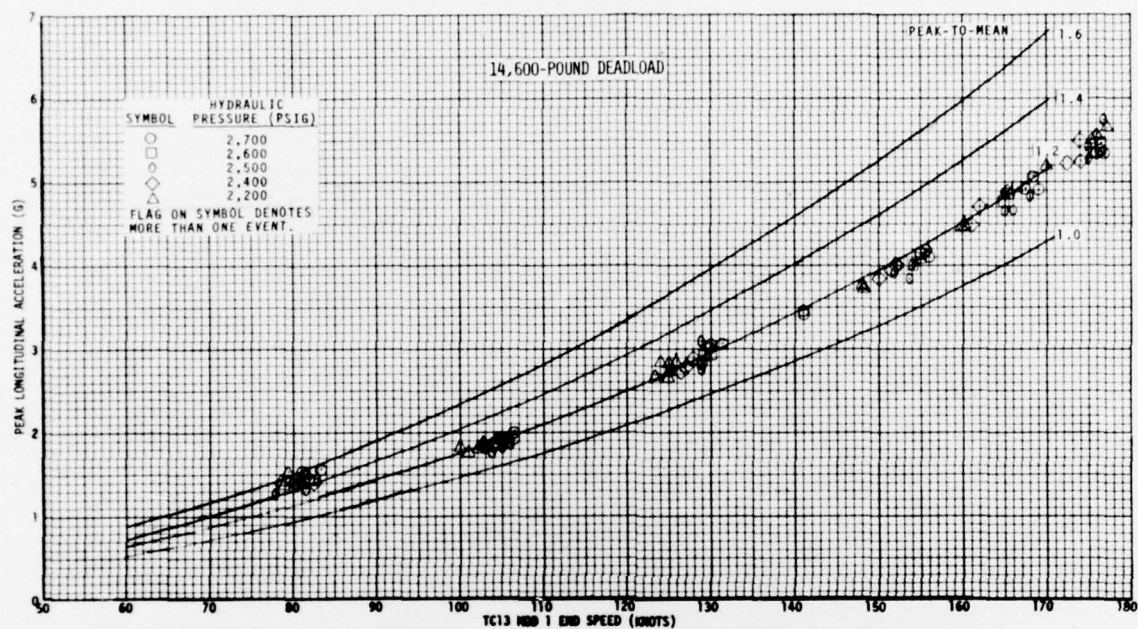


FIGURE 12 - COMPOSITE GRAPHS OF CAPACITY-SELECTOR-VALVE SETTING VERSUS TC13 MOD 1 END SPEED; VARIED HYDRAULIC-SYSTEM SUPPLY PRESSURES (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)



FIGU

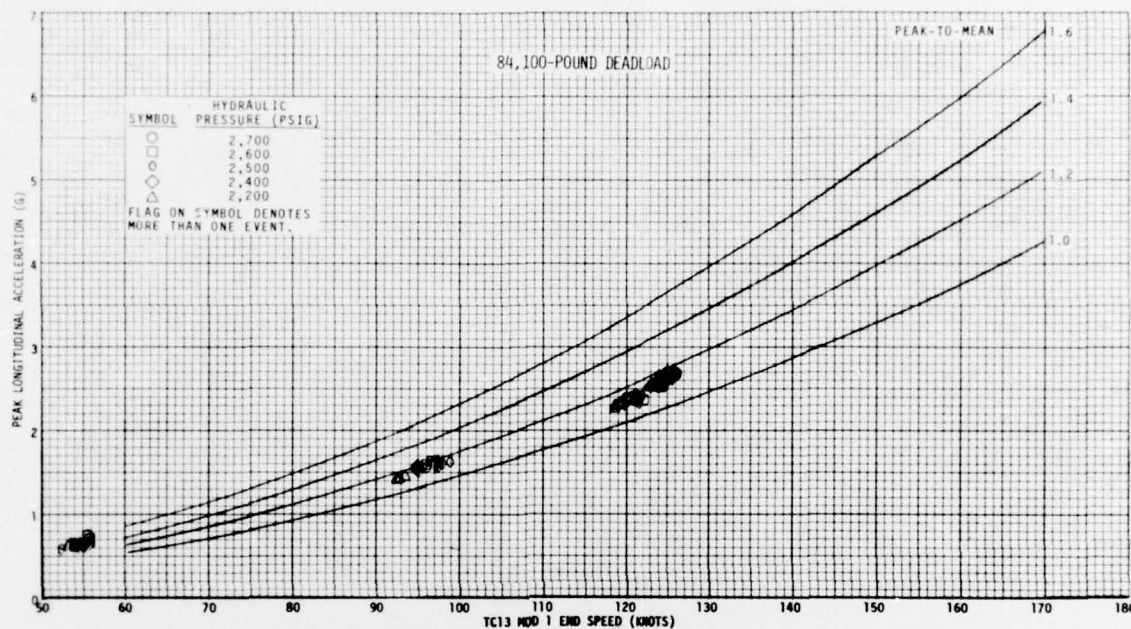


FIGURE 13 - COMPOSITE GRAPHS OF PEAK LONGITUDINAL ACCELERATION VERSUS TC13 MOD 1 END SPEED; VARIED HYDRAULIC-SYSTEM SUPPLY PRESSURES (CVN 68 CATAPULT/DEADLOAD CALIBRATION PROGRAM)

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